COMMONWEALTH OF PENNSYLVANIA.

DEPARTMENT OF AGRICULTURE.

BULLETIN NO. 57.

The Application of Acetylene Illumination to Country Homes.

By George Gilbert Pond, Ph. D.

PUBLISHED BY DIRECTION OF THE SECRETARY.

1899.

WM. STANLEY RAY,
STATE PRINTER OF PENNSYLVANIA.
1900.

COMMONWEALTH OF PENNSYLVANIA.

DEPARTMENT OF AGRICULTURE.

BULLETIN NO. 57.

The Application of Acetylene Illumination to Country Homes.

BY GEORGE GILBERT POND, Ph. D.

PUBLISHED BY DIRECTION OF THE SECRETARY.

1899.

WM. STANLEY RAY,
STATE PRINTER OF PENNSYLVANIA.
1900.


VIRTUE
LIBERTY AND
INDEPENDENCE

TABLE OF CONTENTS.

	Page.
Introduction,	7
Discovery of calcium carbide and acetylene,	11
Literature,	13
The carbides in general,	14
Calcium carbide in particular,	14
Manufacture of carbide,	17
General properties of acetylene,	18
Specific properties of acetylene:	
Acetylene an endothermic compound,	22
Physiological effect of acetylene,	23
Explosibility of acetylene,	24
Combustion and illuminating power,	25
Danger,	28
Impurities in acetylene,	31
Cool generation,	34
Lime dust and pipe clogging,	35
Types of generators,	35
Supply of carbide,	41
Transportation and storage of carbide,	42
Insurance regulations,	43
Generators available,	50
Generators approved by Underwriters other than the Middle Department,	68
Pennsylvania machines,	73
Unapproved machines,	73
Cost of acetylene illumination,	74
Burners,	76
Freezing,	78
Disposition of residuum,	78
Purification,	79
Carbolite,	80
Bibliography,	82

COMMONWEALTH OF PENNSYLVANIA.

DEPARTMENT OF AGRICULTURE.

HARRISBURG, PA., *December 30, 1899.*

The introduction of town and city conveniences into country homes is of the first importance, if the country is to become the residence of people who have been accustomed to these modern comforts. Thorough and economic heating, ample and convenient water supply, proper sanitary drainage, and thorough, safe, and inexpensive lighting, are now necessities for a large part of our population. The use of city gas or electric lighting, is not generally practicable in the country, and residents have been, until quite recently, compelled to use kerosene or gasoline for light. The new illuminant, Acetylene, which has now been tested to a considerable extent, has attracted the attention of residents in rural districts, and, if found to be safe, and easily controlled, will supply a brilliant and cheap illuminant very much needed.

Dr. G. G. Pond, of the Department of Chemistry of the Pennsylvania State College, was engaged to make a thorough examination into the use of this new illuminating gas and its adaptability for use in country homes. The results of his investigations are given in the Bulletin herewith presented, and will interest many who are looking for a suitable method of Home Lighting. This Department makes no recommendations in the use of Acetylene Gas, and only presents the subject for the information of the public, leaving each individual to judge for himself as to its desirability for his use.

JOHN HAMILTON,
Secretary of Agriculture.

THE APPLICATION OF ACETYLENE ILLUMINATION TO COUNTRY HOMES.

By George Gilbert Pond, Ph. D., Professor of Chemistry, State College, Penna.

INTRODUCTION.

An old writer, I do not recall what one, relates that after sunset Nineveh was illuminated in its streets and palaces, by lights so brilliant that it was difficult to distinguish night from day. In such an account it is doubtless necessary to make ample allowance for exaggeration, yet the fact remains that we have lost all hope of ever knowing by what kind of light Nineveh and Babylon were illuminated. Still, recent discoveries permit us at least to hope that in our towns lighted by acetylene, this artificial sunlight, as we are wont to call it, night shall be no more regretted than day.

For a moment it would be well to glance at the past and review the years as they have advanced. The Greeks and Romans lighted their cities in primitive fashion with *torches* which were mere pieces of resinous wood, or with metallic tubes containing tow soaked in pitch or resin, or with *candles* made of tallow, resin or wax. Later came lamps, vessels made of burnt clay, or of metal, filled with oil and provided with a wick. The many specimens of lamps which ancient Rome has bequeathed to us present a great variety, often of marvelously graceful forms. The artistic merit of the antique Roman or Grecian lamp is well known, but naturally enough, neither the beauty nor the richness of the vessel could prevent the flame from being smoky and dim. There were also *candelabra*, supporting several lamps or flames, as well as *lanterns*, the walls of which were of translucent horn or of bladder, and in later days of glass, and until comparatively recent times our ancestors possessed no other means of illumination.

Under these conditions, one can readily understand that it was difficult to light city streets at night. Imperial Rome was indeed illuminated on the occasion of certain important festivals. In France,

the royal ordinances which required the inhabitants to maintain a certain number of lamps in each quarter, remained a dead letter till the middle of the seventeenth century. Louis XIV delighted in adorning his capital; he provided, therefore, for the security of its streets which were tortuous and notoriously beset with criminals. By letters patent, dated August 26th, 1662, the King ordered the establishment of movable lights to be placed at the disposal of the public. Torch bearers and lantern bearers were stationed every eight hundred paces in all quarters of the city, and let themselves to each comer, accompanying him a quarter of an hour for the consideration of a few coppers.

Only a few years later, a progressive lieutenant of police compelled the citizens to maintain lanterns during the winter in each quarter, and thus organized a definite system of lighting. A decree of Parliament, May 23d, 1671, fixed the commencement of the season at October 20th and the end at May 31st. The seventeenth century saw, before its close, six thousand five hundred lanterns, consuming each night in the streets of Paris, sixteen hundred and twenty-five pounds of candles. Strangers never tired of expressing their admiration of the novel illumination. Dr. Lister, a famous English traveler, writes his impressions, upon his return from Paris in 1688, as follows:

"The streets are lighted all winter, as much when the moon is visible as during the rest of the month. I remark upon it especially, because of the stupid custom which prevails in London of extinguishing the lanterns during half of the month as if the moon must surely be brilliant enought to light the streets, and as if it were impossible for the sky to be clouded in winter. These lanterns are suspended right over the middle of the streets, twenty feet high and a score of paces apart. They are furnished with glass about two feet square and have covers of sheet iron. The cord which suspends them is fastened, under lock and key, to the wall of a neighboring house. In the lanterns are candles sufficient to last till after midnight."

Perfection was far from reached, but in those times people knew how to be contented with little. Illumination, public and private, made no notable advancement before 1764. At this time a man of great intelligence and energy was made chief of police in Paris. He offered a reward to that inventor who should perfect the illumination of the streets. At his suggestion the Academy of Science offered the extraordinary prize of two thousand pounds to the writer who should treat in the most approved manner the subject, "The Best Means of Lighting at Night the Streets of a Great City, Combining Brilliancy, Easy Accomplishment and Economy." Lavoisier presented a memoir and received a gold medal, but the model adopted was that of another who invented an oil street lamp. The apparatus was so remarkable that a prominent statesman of that time wrote to

the King, "The light which it gives precludes the thought of anyone ever finding anything better." However something better was found, and in 1821 the Argand chimney was adapted to the street lamp, and increased, to a remarkable degree, the intensity of the flame. Argand was a Genevese chemist, a pupil of the famous Swiss naturalist Saussure. He had completed his university studies in Physics and Chemistry, and had presented to the Academy a number of remarkable addresses when he invented his lamp with a double current of air, first made in England in 1782. The Argand lamp, however perfect it may have been, had one fault; the level of the oil could not be maintained rigidly constant. A clockmaker, Carcel, solved this problem by attaching to the lower part of the Argand lamp a little force pump driven by clockwork, the office of which was to raise the oil contained in the lower receptacle to the wick. This new lamp acquired for a short time a just notoriety; it was called the Carcel lamp; science adopted the name, and the Carcel became the recognized unit of light. From the Carcel lamp to the Moderator was but a step. Franchot invented the latter by simplifying earlier forms, substituting a spiral spring for the clockwork, and thus came into use a style of lamp employed up to the present day.

During this perfecting of illumination by oil, the candle industry was suffering a transformation. Many investigators had attempted, with little success, to employ the fatty acids in illumination. Meantime the revolution of 1830 was declared. De Milly, a courtier of Charles X, seeing his career suddenly broken off, sought a fortune in this industry, and devoted himself to investigation which resulted in the greatly improved stearine candle so popular to-day.

Meantime public lighting had commenced to develop in a new direction. Krueger succeeded, in 1786, in extracting from coal a quantity of gas, sufficient to light the Jesuit College of Stony Hurst in Lancashire, but as this impure gas yielded only a smoky flame, his experiments were discontinued. The same year the chemical laboratory of the University of Würzburg in Germany was lighted with the gas obtained by the dry distillation of bones.

In 1791, Le Bon, a young French engineer, discovered that the gas liberated from calcined wood was ignitible and yielded a brilliant flame. With indefatigable energy he pushed the development of his discovery, and in 1802 accomplished the successful illumination of his house with this gas. But history gives to William Murdoch, the Englishman, the honor of being the true inventor of gas lighting, since he in 1792 lighted his workshop in Cornwall with gas obtained from soft coal. Ten years later Murdoch had established quite extensive gas works near Birmingham, the factory in which James Watt had constructed his steam engines, being one of the buildings to be thus illuminated, but it was not till 1812 that gas lighting was

adopted to any considerable extent in London. A German named Winsor, who had kept himself acquainted with the results of Le Bon and Murdoch, succeeded in breaking down the powerful prejudice which existed in England against the innovation, lighted the Lyceum Theater with gas in 1803, and in 1810 founded the first gas company in London. From England, Winsor went to France, where Louis XVIII gave him every facility for exploiting the novel method of illumination. In the face of all sorts of prejudice the industry made steady advances, and the year 1820 saw its introduction to all the larger continental cities.

Oil gas has had a considerable career, and is used to enrich other gases or is burned by itself; it is made by injecting crude oil into hot cylinders or retorts, called the "cracking" process, because the heavy oils, of shale or tar origin, are thus broken up, or cracked, into light gases.

Water gas, made by the action of steam on red hot coal, though itself non-luminous, is rendered suitable for illumination by impregnating it with gases derived from oil, a process familiarly known as *carburetting*. This gas has had an immense effect upon the gas industry of the world, especially in our own country, where either alone, or accompanying the coal gas manufacture, it is known in every large city of the land.

Petroleum, introduced into the markets of the world within the last half century, replaced to a large extent the other oils which had been employed in the earlier forms of lamps, but did not revolutionize the methods of producing light.

Dr. von Welsbach, an Austrian chemist, has outstripped all competitors in solving the problem of securing the most light from little gas. The Welsbach, or incandescent mantle is composed of incombustible material dipped in a solution of the rare earths, thoria and ceria, which have the property, when highly heated, of emitting a most powerful light. Placed over a Bunsen flame this mantle produces a brilliant light whereby the candle power of coal gas is increased three-fold. In this invention, gas companies possess a most powerful weapon which they are to-day wielding with great effect in the struggle against electricity.

Electric illumination, whose history is familiar to all of us, has given gas illumination a real competition, though its cost has prevented a destruction of the gas industry.

And now *acetylene*, a name only yesterday unknown to those who do not frequent the laboratories of science, but to-day on everybody's lips, is rapidly spreading over all civilized parts of the globe, in spite of the pronounced hostility against it, compelling the new illuminant to stand in the position of one who is adjudged guilty until he can prove his innocence. Illuminating gas itself obtained a foothold in

England only after severe and bitter struggles, as illustrated by the fact that when, after many and prolonged controversies, its promoters finally secured the permission to light the Houses of Parliament, the authoritative document contained the condition that pipes conveying the gas "shall be placed upon brackets at least eighteen inches from the wall." And later, in Philadelphia, in the early thirties, the people presented a "Remonstrance Against Lighting with Gas," which contained the following wisdom: "We consider it a most inexpedient, offensive and dangerous mode of lighting. We consider gas to be an article as ignitible as gunpowder, and usually as fatal in its results." So it is perhaps not to be wondered at that this new form of illuminating gas, possessed as it is of unfamiliar characteristics, should meet with decided opposition.

It is the aim of this investigation to carefully and disinterestedly study this new gas, Acetylene, and the marvelous stone from which it is made, one of the most wonderful of many discoveries of this last decade of a century prolific in marvels, the Carbide of Calcium.*

DISCOVERY OF CARBIDE OF CALCIUM AND ACETYLENE.

As early as 1836 Edmond Davy, an English chemist, observed that a by-product which he had secured incidentally to the production of metallic potassium, was capable of decomposing water with the evolution of a gas which contained acetylene. In 1862 Woehler, the greatest chemist of his day, announced the discovery of the preparation of acetylene gas from calcium carbide, which he had made by heating to a very high temperature a mixture of charcoal with some alloy of zinc and calcium. The product could decompose water, like Davy's compound, and yield a gas containing acetylene. Thus the phenomenon which had been observed but not understood by Davy, was explained and published by Woehler, and to him belongs the honor of the discovery of calcium carbide and of acetylene. Woehler further pointed out that the new gas burns with a brilliant but very smoky flame, and announced several other characteristics, though it remained for Berthelot, in the same year, to very exhaustively study and describe these new compounds.

Then for nearly thirty years these two substances seem to have been practically forgotten. During all this time acetylene was pro-

*NOTE—Portions of this introduction have been translated and adapted form Capelle's L'Éclairage à L'Acétylène.

curable only by the tedious methods which the early discoverers had used, with the result that even its name was known only to students of science, and it is perfectly safe to say that up to 1892, few even of the professional chemists of the world ever saw an acetylene flame, much less dreamed of it as a commercial possibility.

But with the development of the modern electric furnace, whose high temperature places in the hands of the investigator a means of bringing about the chemical changes never before known, the laws which govern its formation could not longer remain undiscovered. Just as the possibility of Carborundum, that most useful of abrasives, was revealed to the Pennsylvanian, Acheson, through the instrumentality of the electric furnace, so through the same means, in a similar manner, and at about the same time, the possibility of calcium carbide as a commercial product was revealed to Thomas L. Willson, an electrical engineer at Spray, in North Carolina. This gentleman was conducting experiments, with a view to the preparation of metallic calcium, for which purpose he employed an improved Héroult electric furnace with a current of two thousand amperes and thirty-six volts, operating upon a mixture of lime and coal. He secured a melted mass of dark color, which on cooling became solid and brittle. Willson is said to have discarded this product, as it was clearly not the material for which he was searching, metallic calcium. It was thrown into a neighboring stream, when to the astonishment of those who saw, there was suddenly liberated a great quantity of gas, which on being kindled, burned with the now familiar bright but smoky flame. The smelt was repeated; the product submitted to analysis, and on the 16th of September, 1892, a specimen was sent to Lord Kelvin, in Glasgow, with a letter which has since become a famous document in scientific history, since it secures to Willson the honor of being the first to prepare calcium carbide on a scale large enough to promise commercial results.

Thus calcium carbide is no *new* thing, since it has been known for the greater part of the century now closing, but the possibility of its manufacture in quantity dates only from these experiments at Spray, in 1892.

To be sure, the French chemist Moissan and others, were occupying themselves with similar investigations during the same time, and Moissan in particular has communicated to the world the results of a thorough study of this and other carbides. True it is, that there has been a legitimate controversy between the supporters of the French savant, and the friends of the American experimenter, with regard to the right of priority of discovery, with the result, after the question has been thoroughly investigated, that outside of France at least, scientific men do not fail to agree that to Willson belongs the honor. The German government has acknowledged it in a most sub-

stantial way, by annulling the German patents first granted to Bullier. Thus through the incidental study of a by-product, and as the result of a chance accident, was the industrial possibility of calcium carbide discovered, and made known to the world. To-day calcium carbide and acetylene are familiar terms upon the lips of all the people of every civilized country of the globe.

LITERATURE.

Previous to the last few years, the literature of our subject would naturally not be looked for outside of the most remote scientific prints, those journals which are made for the scientific classes only and read by them alone. But within seven years, practically within five, has sprung up a voluminous, popular and semi-popular literature on this subject. For those who devote their attention to acetylene, there are special acetylene periodicals; two are regularly published in Italy, one in France, two in Germany, one in England, one in the United States, all journals of respectable size, responsible editorship, and regular issue; possibly there may be more, of which the writer has no knowledge, but four of these are regular comers to his table while this article is in preparation. Moreover, volumes have been written, lectures delivered and publisned, and numberless articles for the press have spread the knowledge of acetylene to the remotest corners of the globe. One who desires to follow the history of this gas in some detail, would do well to consult the files of the Progressive Age,* whose editor has given to the claims of acetylene for recognition, most fair and careful consideration. The issues of this journal from about 1894 down to date furnish the general reader with a most excellent account of the growth and development of acetylene illumination.

The manufacture and supply of carbide has been the subject of several consular reports, as many requests have reached the Bureau of Foreign Commerce for information on the subject from different sources.

Further, the patent literature of all countries has accumulated bulky volumes, first, on the manufacture of carbide, and second, on the development of generators. Acetylene machines have presented to amateur inventors an attractive field, both because of the obvious usefulness of these generators, and because of the readiness with which new ideas in feeding carbide and water, one to the other, can be devised. Thousands of people from all walks of life have planned new forms; among them are butchers, priests and bakers. The United States Patent Office has granted five hundred and fifty-one patents up

---

* The Progressive Age, semi-monthly, 280 Broadway, New York, E. C. Brown, Editor.

to the close of 1899, and applications have been coming in for many months at the rate of fifty to seventy per month.

For a further view of acetylene literature, the reader is referred to the bibliography of this subject which appears at the end of this article.

THE CARBIDES IN GENERAL.

By a carbide, those who familiarize themselves with the concise language of science, understand nothing more nor less than a compound or substance composed of charcoal and a metal. But these two parts are so blended into each other, chemically combined, that the characteristics of both are entirely lost in the properties of the product. So far as we know, there may be carbides of all the metals, and certain of these are known. Thus potassium carbide and sodium carbide have been studied and the results published; we can read, if we wish, about the carbides of barium and of aluminum. Carbides of iron, or iron carbides, play an important role in the metallurgy of iron and steel, but the two carbides which are of leading commercial importance are those of silicon and of calcium. The former constitutes Acheson's carborundum, the highly valued, new abrasive material, while the latter is of importance for no valuable properties which it possesses in itself, but because from it can easily be made the new illuminant, Acetylene. The carbides, as a class, are solid substances, not easily melted, uninflammable, hard, unattractive in appearance (carborundum is an exception to this), and about two and a half times as heavy as water. They possess in common no valuable property except that when brought into contact with water, certain of them, not all, have the power of entering into chemical combination with the water, after the manner in which lime slakes with water, but with copious liberation of bubbles of gas. Of those which do this the one of greatest practical importance, and the cheapest, is the carbide of calcium, or we may use interchangeably at pleasure, with equal propriety, the slightly different name, calcium carbide.

CALCIUM CARBIDE IN PARTICULAR.

This compound and its peculiarities should here be described in considerable detail. Deferring the method of its preparation to a later section, it may here be mentioned that calcium carbide is a hard, dry, opaque, solid substance, known to the chemist as $Ca\ C_2$; which, not to be alarmed at the suggestion of a chemical formula, is merely a short hand expression for one unit of mass of calcium, the metal which exists in lime, combined with two mass units of carbon, the element of which charcoal is composed. Calcium carbide is therefore nothing more nor less than a compound which contains calcium

and carbon. The calcium in it is about 62.5 per cent. and the carbon is 37.5 per cent. of the weight of the carbide. We all know that the common ore of iron, which is so familiar, is composed of iron and oxygen, and yet the compound is far different from the iron which it contains and which we know can be smelted out of it, also very different from oxygen, the air which we breathe all the time; we are quite accustomed to feel that the iron is there in the red ore, and the oxygen is there to, though in a substance having properties quite different from either. It should therefore be no difficult matter for us to understand that calcium, a metal, and carbon, a substance like coal, are both contained in this material, calcium carbide, though the compound is so different from either constituent.

Calcium carbide is generally of a dark brown or black color, sometimes described as dark gray, and sometimes as a bluish black, and often possessing a reddish tinge. It is crystalline and brittle. Its specific gravity is 2.22 to 2.26; it endures heating to redness without melting or suffering other change though it softens and fuses under electric heat; it will not burn, except when highly heated in oxygen gas; it looks like a mass of stone. It may be preserved any length of time if kept sealed from air, but the ordinary moisture of the atmosphere gradually slakes it and it becomes changed on long standing into slaked lime, not essentially different from other air-slaked lime. This slaking power gives it a name, which is sometimes heard, Acetylene Lime. It always possesses a penetrating odor, which however is not due to the carbide itself, but to the fact that it is constantly decomposing with moisture, yielding minute quantities of acetylene gas which accounts for the odor rather than the carbide itself. It is not affected by solvents, such as carbon bisulphide, petroleum, chloroform, ether or benzine, but if allowed to come into contact with water, or any mixture containing water, an immediate and vigorous decomposition takes place evolving liberal quantities of gas. Carbide is a safe substance to store or transport under proper conditions. It can not explode, take fire, or otherwise do harm, being similar to lime in this respect also. Since even the slow action of the moisture ordinarily present in the air will in time render carbide entirely useless, it becomes absolutely necessary, in order to securely preserve it, to pack it in perfectly tight, closely sealed containers, generally drums or cans. Granted protection from water, no substance can be safer or less likely to cause trouble when stored or conveyed from place to place. Lime becomes very hot when acted upon by water, so also does carbide, and the only essential difference is that carbide, when it slakes with water, yields a combustible gas. But this is the very fact which makes it interesting and valuable. Carbide decomposes with water in accordance with the following chemical equation:

CaC_2	+	$2H_2O$	=	$Ca(OH)_2$	+	C_2H_2
Carbide	and	water	yield	slaked lime	and	acetylene.

An easy calculation shows that sixty-four weights of carbide require thirty-six of water, producing also seventy-four weights of slaked lime and twenty-six of gas. But as gas is more conveniently and commonly measured than weighed, a better statement of the same fact would be: A pound of absolutely pure crystallized carbide yields 5.5 to 5.8 cubic feet of acetylene. Yet absolute chemical purity it not a practical commercial possibility, and it is natural to suppose that a commercial product will vary in purity. Calcium carbide is no exception. Special reasons for this will be observed later, but in practice, carbide may generally be expected to produce never less than four and a half cubic feet, measured at ordinary temperature, and rarely more than five and a half cubic feet per pound of carbide; it may ordinarily be calculated at five. It is important to remember that the exact proportional weights of water and carbide must always enter into combination, i. e., sixty-four of actual carbide to thirty-four of water, be it ounces, pounds or tons; also that the same proportional weight of acetylene must always result. Any apparent exception can only be due to impure carbide, loss of gas, or failure to secure complete consumption of material.

The evolved gas does not take fire of itself but is easily lighted. Let anyone take a tumbler of water and drop into it a piece of carbide, the size of a pea, then let him light the bubbles of gas as they rise to the surface. In no way is it easier to secure a practical knowledge of the characteristic properties of this wonderful stone. The gas burns with a bright light, not brilliant, for it needs control to bring out this property, and much smoke. In fact soot in solid flakes may be seen floating through the air when this experiment is performed in this rough way. While carbide, as stated above, is not inflammable, nor possessed of any explosive property, such as is sometimes erroneously attributed to it, it might, by finding access to water in a closed vessel, create such a pressure as to burst the vessel, and it is not impossible that the heat generated might cause an ignition of the gas with resultant disaster. But any such condition as water and carbide gaining access to each other in a confined space, is most improbable; could only occur by intention, and may be dismissed from the list of possible accidents.

When water is to be sprinkled or sprayed upon carbide, in not excessive quantities, the resultant slaked lime is left in a perfectly dry and dusty condition, occupying considerably more space than the original carbide. When more than enough water is employed, the residuum will of course be wet, either pasty, or thinner if large excess of water is employed.

THE MANUFACTURE OF CARBIDE.

It is the very high temperature attainable in the modern electric furnace, four thousand five hundred degrees Fahrenheit, which alone accomplishes the combination of the elements to form calcium carbide, and it is not necessary to attribute it to the action of any electric force or process. The electric "arc" being formed in the furnace, a thoroughly incorporated mixture of ground coke and lime in right proportion is introduced. The change which takes place is:

$$\underset{\text{Quick lime}}{CaO} \quad \underset{\text{and}}{+} \quad \underset{\text{coke}}{3C} \quad \underset{\text{yield}}{=} \quad \underset{\text{calcium carbide}}{CaC_2} \quad \underset{\text{and}}{+} \quad \underset{\text{carbon monoxide.}}{CO},$$

which means that fifty-six pounds of lime and thirty-six of coke make sixty-four of carbide and liberate twenty-eight of carbon monoxide gas, which escapes or is burned at the mouth of the furnace. Thus for each pound of carbide made, is consumed a pound and a half or more of a mixture which is something like seven-twelfths lime with five-twelfths coke. Granted pure material, there is formed an ingot of very pure carbide, surrounded by a crust of less pure product because partially unconverted. In breaking up, packing and shipping the carbide, this poorer crust is partly rejected; but another portion is mixed with the ingot and to some extent reduces the average gas-yielding power or the carbide, which finds its way to the market. It is by no means a difficult matter to test a sample of carbide for its yield of gas, and it would always be well in purchasing carbide, to do so under guarantee that it shall come up to a stipulated test as shown by its gas-yielding capacity. At first, impure materials were employed for the manufacture of calcic carbide, but this resulted in an inferior grade of carbide, which in turn yielded an impure gas, so that at the present time it is everywhere recognized as essential, that only first class materials should be used. It is customary to employ lime which is 99 per cent. pure, and coke of low ash. Both must be as low as possible in sulphur and phosphorus.

The Union Carbide Company of New York, is at present practically the sole manufacturer of carbide in the United States; it is licensed by the Electro Gas Company under patents controled by the latter company. It manufactures one grade of carbide, and sells it as strictly high grade, capable of yielding five cubic feet of gas to the pound.

Of impurities in carbide and in acetylene, mention will be made under a later topic.

GENERAL PROPERTIES OF ACETYLENE.

Acetylene gas, whether prepared from carbide or in any other way, is known to the chemist as C_2H_2, meaning that it has the constant composition of twenty-four parts by weight of carbon and two of hydrogen, or ninety-two and three-tenths per cent. carbon and seven and seven-tenths per cent. hydrogen. Being composed of these two elements only, it belongs to the class of compounds known as hydrocarbons, represented in nature by natural gas, petroleum, etc. All hydrocarbons are combustible, forming as products of combustion, carbon dioxide and water. There are hundreds of hydrocarbons known, of greater or less importance, and more or less thoroughly studied, and there are many thousands of compounds containing carbon united with elements other than hydrogen, but among them all there is no gas containing a higher percentage weight of carbon than acetylene. It is, therefore, proper to look upon acetylene as gaseous carbon. Carbon, known in so many forms as a fuel for combustion, with a view either to producing heat, or furnishing light, a constituent of all fuels from whatever source and wherever employed, is in no place to be had more approaching the condition of pure carbon in the gaseous state than in acetylene. Pure carbon, one hundred per cent., as well as in the various commercial forms, anthracite, coke, charcoal, etc., does not even melt under such heat as can be attained, much less pass into the form of vapor or gas. Hence it is interesting to note that acetylene, having only seven and seven-tenths per cent. of material other than carbon, is the nearest approach to gaseous carbon at common temperatures with which we are acquainted.

Acetylene is a colorless gas, possessed of a peculiarly penetrating and offensive odor. The offensive nature of the odor is rightly attributed, in large measure, to minute quantities of impurities which the commercial gas may contain; and it is true that when the last trace of these impurities is efficiently removed and the acetylene rendered absolutely pure, the odor becomes far less objectionable and may even be described as etherial. But in describing the gas as it is most frequently known, this intolerable odor should not be ignored. Its presence in the air to the extent of only one part in ten thousand is distinctly perceptible; it is said also to affect the eyes, producing a smarting sensation. It should be observed, however, that in burning properly at the jet, there *absolutely no odor perceptible*, , and if an odor of acetylene is detected about an apparatus in operation, it is certainly because of the leakage of the gas, through faulty piping, an open cock, or otherwise.

Acetylene dissolves in water to a considerable extent. This is usually stated as thirteen volumes of acetylene in twelve volumes of

water. This statement is for ordinary temperature, approximately correct, and it is near enough for practical purposes to state that a gallon of water may dissolve a gallon of gas. It is more soluble in certain other liquids, noticeably, acetone, but there is little practical reason for considering, here, its solubility in any other liquid than water. The full measure of the solvent power of water for acetylene is not reached unless the gas and the water are given ample opportunity to come into free contact with each other. Thus if the gas be kept within a receptacle over water which is at rest, the surface layer of water to a slight depth becomes saturated with the gas; protects the lower layers of water from becoming so, and the further penetration of the gas into water is retarded or even stopped. But if the water is agitated in any way with the gas, or the gas allowed to bubble up through the water, the water easily takes up its full allowance of gas, and under such circumstances the withdrawal of a quart of water involves also the removal of the contained quart of gas. This idea of the solubility of a gaseous substance in water is a peculiarly difficult conception to grasp, but if we may just accept it as fact, and consider it parallel with the solution of salt or sugar in water, we shall be on the right track in this respect. Acetylene is lighter than air in the proportion of ninety-one to one hundred; its specific gravity is therefore said to be 0.91. A balloon filled with it will consequently float in the air. Yet it is much heavier than coal gas whose average specific gravity is 0.43; or natural gas, 0.56.

Acetylene burns in the air with a brilliant but smoky flame. When its illuminating power is properly brought out, it yields a light of greater brilliancy than that furnished by any other gas. All hydrocarbons burn in air with production of carbon dioxide and water, but the quantity of combustion products compared with the volume of gas burned, varies with the character of the hydrocarbon used.

The combustion equation,

$$\underset{\text{Acetylene}}{2C_2H_2} \underset{\text{and}}{+} \underset{\text{oxygen}}{5O_2} \underset{\text{yield}}{=} \underset{\text{carbon dioxide}}{4CO_2} \underset{\text{and}}{+} \underset{\text{water,}}{2H_2O}$$

means that two volumes of acetylene burned require five volumes of oxygen and yield four volumes carbon dioxide and two of water vapor. Better stated, one cubic foot of gas burned deprives the surrounding air of two and one-half cubic feet of oxygen, and throws into it two cubic feet of carbon dioxide and one of water vapor. Here, of course, is meant the complete combustion as it takes place in a perfect burner, and space will not be consumed in considering imperfect, or retarded or partial combustions which are possible, but are aside from the line of importance.

All gases which burn in air, will, when mixed with air previous to ignition, produce more or less violent explosions, if fired. Com-

mon illuminating gas, issuing quietly from the jet where it has been lighted, burns regularly and safely with no suggestion of explosion. But allow the gas to become mixed with air as by accidental leakage into a cellar or closet or other confined and unventilated place, then bring about its ignition by applying a flame as when a match is lighted in the vicinity, or one goes into the dangerous place with a lighted lamp or candle, and an explosion is sure to result which is more violent as the mixture more nearly approaches the proportions necessary for combustion. This is a perfectly general fact, as true of one combustible gas or vapor as another. Creative Power endowed all ignitible gases with this property and it is as sure to be true as water is to flow, be it in the coal mine, at the gas works, along a leaky city main or in the bowl of an overheated oil lamp.

Of course acetylene is no exception. From the statements just presented it is easily calculated that one measure of acetylene and twelve and a half of air are required for complete combustion; this is also the proportion for the most perfect explosion, i. e., mixtures of acetylene and air which contain about seven and one-half per cent. of the gas are expected to explode with the most terrific violence. But let it not be supposed that a seven and a half per cent. mixture is the only one which can explode with violence; *all* mixtures from three per cent. to eighty-two per cent. of acetylene in air are capable of an explosion with greater or less force according to conditions. Acetylene possesses a somewhat wider range of explosibility than do similar gases. This one point alone considered, acetylene might therefore be regarded as more dangerous than other gases, but as will be shown in a section on Danger, in view of the conditions under which acetylene is employed, this is not a faithful statement of the case.

The ignition point of acetylene is lower than that of coal gas, being about nine hundred degrees Fahrenheit, as against eleven hundred degrees. And the temperature of its flame is eighteen hundred degrees Fahrenheit, as against two thousand four hundred and fifty degrees to two thousand five hundred degrees Fahrenheit for coal gas. This means that relatively, acetylene burns with a distinctly cool flame.

Under comparatively light pressure, twenty-six atmospheres, at thirty-two degrees Fahrenheit, a measure of compression easily reached with modern pumping appliances, acetylene gas becomes a liquid. This liquid is said to be the lightest liquid known, being only four-tenths as heavy as water. It is possessed also of an expansibility greater than that of any other known liquid. Acetylene may further be had in a solid form, resembling snow, and this is called acetylene snow, bearing as it does to liquid acetylene and acetylene gas, the

same relation that ordinary snow bears to water and steam respectively.

Acetylene in the gaseous form, at ordinary pressure, is not explosive in any sense except as referred to above, when mixtures with air become ignited. So important is the correct understanding of the exact facts in this matter that, even at the expense of some repetition, it should be clearly understood that acetylene gas, *not compressed*, *cannot* be exploded, detonated, or otherwise set off in any manner whatever that could warrant its being called explosive. A lighted candle plunged into it will be extinguished, setting fire to it, of course, where it comes in contact with air, for air is necessary for its combustion; but no combustion or explosion can take place in the midst of a body of the gas. Even a fulminate cap exploded in the gas will not propagate a wave of explosion to any perceptible extent whatever, nor will an electric spark in an atmosphere of the gas cause any injurious or dangerous result whatever, except such as would result from lighting any other gas in the same manner.

But the liquefied gas, liquid acetylene, is quite another matter. Under certain conditions, not necessary here to analyze, liquid acetylene can be exploded, and for that reason liquid acetylene may be set down as a dangerous substance. Even this preparation, when our knowledge of it becomes more perfect, may perhaps be so controlled as to render its restricted employment safe, but for the present, a wise rule is to allow no liquid acetylene to be handled under circumstances where its explosion might do harm. In fact it would be wise to go still further and avoid the use of acetylene under any pressure which might by any possibility approach the pressure necessary to liquefy the gas. The liquefying pressure has been mentioned as twenty-six atmospheres, at thirty-two degrees Fahrenheit; this means nearly four hundred pounds per square inch at freezing temperature and much more than that at temperatures at which one would be likely to operate.

No one could, by any reasonable possibility, accidentally liquefy any acetylene, and so the safeguard is a perfectly easy one to apply, and in all appliances in which acetylene gas is prepared and used, the likelihood of creating a dangerous compression is reduced to nothing. It is still further true that acetylene, at some pressures, greater than normal, but not approaching very closely that necessary to liquefy, has under most favorable conditions been found to explode; hence the necessity of avoiding the use of any sort of pressure apparatus; but it may be said with perfect confidence, that this gas has been studied a very great deal and its properties are as well known as could be wished, yet under no circumstances has anyone ever secured an explosion in it, if subjected to less than one atmosphere of pressure. And as the limit of one atmosphere, fifteen pounds to the

square inch, is a perfectly easy one to observe, and as in the usual apparatus there should never be a pressure of more than a few ounces, the conditions of safety along this line need by no means be over-reached.

Though not exploded by application of high heat, acetylene is injured by such treatment. More properly speaking, it is partly converted, by high heat, into other compounds thus lessening the actual quantity of the gas, wasting it, and polluting the rest by the introduction of substances which do not belong there. Among such compounds into which acetylene, C_2H_2, may be partially converted by heat, are benzol, C_6H_6, and styrolene, C_8H_8. These and others of their like remain in part with the gas causing it to burn with a persistent smoky flame which cannot be corrected, and in part deposit a solid tarry residue at the point where the heating takes place. In cases where the gas is generated without avoiding undue rise of temperature, objectionable results as above are certain to be secured.

Compounds of acetylene with copper and silver have long been known and they are violently explosive substances. They are easily made in the laboratory if one takes the trouble to make the experiment, and it has been supposed that the copper compound might be formed by action of the gas on copper or brass containers, pipes, parts of apparatus, fixtures, etc. But careful investigations, during which acetylene gas has been allowed long contact with copper and brass, under more varied and trying conditions than would ever be likely to exist in practice, have been repeatedly and laboriously carried out, and the idea that such conditions can result in the accidental formation of dangerous substances has been entirely set aside as disproved.

SPECIFIC PROPERTIES OF ACETYLENE.

ACETYLENE AN ENDOTHERMIC COMPOUND. A great deal has been said by those who feel that they can afford to use scientific terms, about acetylene being an endothermic substance. This bugbear may as well be disposed of once for all, and we shall find that the name is a great deal worse than the condition which it describes, as regards acetylene at least. There are certain compounds during the formation of which heat has been absorbed, instead of evolved, as is the usual rule. Such compounds are scientifically described as endothermic, and some of them, because of their power of developing much heat when they decompose, are very explosive substances. Acetylene *is* endothermic, and if pressure be exerted upon it, forcing its parts nearer together, and compelling it to occupy less than its accustomed normal amount of space, it develops the character of an explosive. The only trouble with the use of the word resides in the danger to the inaccurate assumption that an endothermic substance is of neces-

sity also an explosive one. Acetylene at ordinary pressure is not an explosive.

PHYSIOLOGICAL EFFECT OF ACETYLENE. Statements have been made to the effect that acetylene gas is poisonous. These statements are in a general way untrue, though it could not properly be stated that they are wholly without foundation. Reliable investigators, Berthelot, Rosemann, Gréhant and others, whose conclusions are not to be questioned, have independently of each other, carried on researches, not necessary to detail here, but easily referred to when desirable, looking to the establishment of accurate information on this point and have shown that while it is slightly poisonous, it is less so than coal gas and vastly less poisonous than water gas. There is a gas called carbonic oxide, well known to exert a most deleterious action on the blood whenever it is inhaled; this gas is responsible for the poisonous action of furnace and stove gas when, through faulty drafts, household heaters throw out noxious vapors over night, and asphyxiate the householders in their beds. It is the deadly gas which sometimes overcomes persons who breathe the fumes of charcoal burning in confined rooms. It issues from blast furnaces, from kilns of various sorts, and workmen about metallurgical operations, know full well that it is to be avoided. It is insidious and one never knows he is breathing it till the poisonous symptoms commence, for it is without odor, devoid of taste and color, and it kills! One per cent. of it in air is fatal while a much smaller quantity produces bad effects. This gas, carbon monoxide, is a large constituent of water gas, and water gas in all our cities constitutes a great share of the illuminating gas which is sold through the pipes. The writer has heard a high German authority, lecturing before his students in the University of Berlin, descant upon the recklessness of the American people in allowing such a large percentage of carbon monoxide to be present in its city gas supplies. He likened it to the act of a miscreant who goes about putting arsenic in all the wells of a community of people. The writer does not wish to decry the use of water gas in our American towns, on the contrary he believes that sufficient safeguards are exercised against the dangers and that our city gas supplies call for no serious criticism on this score. But acetylene is condemned in advance, said to be poisonous when it is not so, while we go on complacently using a city gas which exceeds acetylene in poisonous character almost as much as arsenic exceeds salt. City gas supplies in America run as high as twenty per cent. of carbonic oxide.

In one of Gréhant's experiments upon dogs, a mixture of twenty per cent. of acetylene with air inhaled for thirty-five minutes did not seem to trouble the animal. A dog breathing a similar mixture of illumi-

nating gas containing only one per cent. carbon monoxide, quickly showed convulsive movements and died after ten minutes.

Acetylene is irrespirable, so indeed is nitrogen or hydrogen, but it is not to be claimed that it is toxic in its action on animal life in any such sense as carbon monoxide is. A very long time of inhalation and very large quantities of acetylene are necessary to bring about symptoms of illness in animals.

EXPLOSIBILITY OF ACETYLENE. It has already been stated that there are two ways in which an explosion can be secured with the aid of acetylene: first, when mixed with air and ignited; second, when, under abnormal pressures, it is set off by concussion. It is important that these two conditions should now be examined a little more closely.

1. *Mixtures with Air.* Acetylene possesses a wider range of explosibility wih air than any other gas. It has been observed under a pervious topic, that all mixtures from three per cent. to eighty-two per cent. of the gas with air explode when kindled. No other gas possesses quite so wide a range; the explosion is also a violent one. Some experiments conducted at the Chemical Laboratory of The Pennsylvania State College would tend to show that acetylene-air mixtures explode with far greater violence than those of other commonly available gases, a fact which would point to its useful application in gas engines.

In the early days of acetylene lighting, it had been suggested to mix the gas with air, previous to conducting it to the burner, the object being to secure a smokeless flame. But in view of the dangerous character of such a mixture, and in view also of some accidents which occurred, this method was given up after the invention of burners, which accomplished the same purpose by effecting a mixture with air right at the point of combustion.

2. *Explosion of Acetylene Under Pressure.* In the first years of the acetylene industry, one of the fondest hopes of its promoters was that the transportation, storage, and sale of the product condensed into liquid form might become an assured success. Some four hundred cubic feet of gas are required to make one cubic foot of liquefied acetylene, and when the pressure is released, the whole quantity of the gas is again secured. The scheme was an ideal one. Houses, streets, or railway cars were to be lighted by gas drawn with the aid of a reducing pressure valve, from a cylinder of condensed acetylene, kept at any convenient point and connected by a pipe to the usual distributing system. But explosion after explosion occurred. One took place in Pictet's works in Paris, October, 1896, in which two workmen lost their lives; and again in December of the same year, a similar accident occurred in Berlin, resulting in four deaths. Liquid acetylene was the cause in both cases. Again in January,

1897, at New Haven, Conn., and later at New York, serious and disastrous explosions occurred. In each of these cases and at other places the disaster was always traced back to the use of liquid acetylene. Many and thorough investigations were made with the result that liquefied acetylene is shown to be a highly dangerous substance. Whether the time will come, as the enthusiasts fully believe, when liquid acetylene can be made and employed with safety, when it shall be known how to so prepare and handle this product as to eliminate the danger in its use, can not now be said. At present, liquid acetylene must be classed as a very hazardous material. Insurance companies very rightly refuse to have anything do with it.

COMBUSTION AND ILLUMINATING POWER OF ACETYLENE. Controlled by a suitable burner the flame of acetylene is absolutely white, and of intense brilliancy. In quality, it is the nearest approach to daylight that we know. Its spectrum closely resembles that of sunlight and consequently all colors appear the same as by daylight instead of being distorted as by gas light, candle, oil or electric light. This property renders it very desirable for ordinary domestic purposes, and also adapts it admirably to photographic and similar uses. Igniting at nine hundred degrees Fahrenheit, and developing a flame temperature of about seventeen hundred and fifty degrees Fahrenheit, it fires more easily and produces distinctly less heat than coal gas, which ignites at about eleven hundred degrees, and has a flame temperature of two thousand five hundred degrees Fahrenheit. It may be ignited from a burning cigar.

Acetylene also pollutes the air less than coal gas, and we may calculate the accuracy of this statement somewhat as follows. Recalling the combustion formula of acetylene:

$$\underset{\text{Acetylene}}{2\,C_2H_2} \quad \underset{\text{and}}{+} \quad \underset{\text{oxygen}}{5\,O_2} \quad \underset{\text{yield}}{=} \quad \underset{\text{carbon dioxide}}{4\,CO_2} \quad \underset{\text{and}}{+} \quad \underset{\text{water.}}{2\,H_2O,}$$

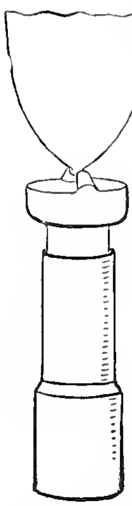
it was pointed out that one meaning to be derived therefrom is that when one cubic feet of acetylene is burned, it takes from the air around the flame two and one-half feet of oxygen and throws out two feet of carbon dioxide gas. Both of these operations vitiate the air in an enclosed room, just as does the burning of any other fuel or the breathing of persons or animals. In the open air, or in perfectly ventilated apartments, this might be ignored, but under usually prevailing conditions, the injury to the atmosphere is by no means insignificant. One foot of coal gas of average composition requires one foot of oxygen and throws out three-fourths of a foot of carbon dioxide; but since only one-half of a foot of acetylene will ordinarily be burned when five feet of illuminating gas would be consumed, it is

necessary for the comparison to multiply these last results by ten, and it will thus be seen that light for light a burner

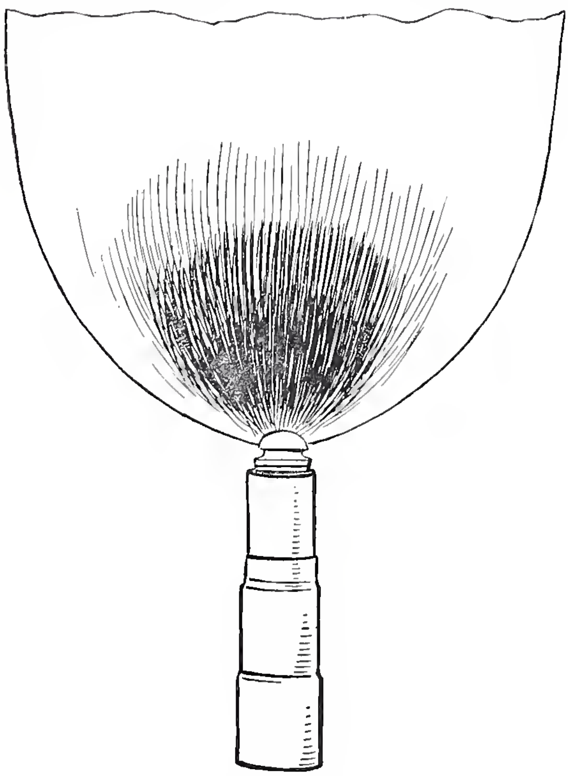
consumes,	yielding,
Acetylene, $2\frac{1}{2}$ feet oxygen,	2 feet carbon dioxide,
Coal gas, 10 feet oxygen,	$7\frac{1}{2}$ feet carbon dioxide.

Or, acetylene in producing the same candle power, impoverishes the air one-fourth as much, and pollutes it also one-fourth as much as illuminating gas. The calculations of Professor Lewes and other authorities are still more favorable to acetylene than are these figures.

"As an illuminant acetylene surpasses in lighting power and economy all other illuminants known; when burned at the rate of five cubic feet per hour it produces light equal to two hundred and fifty candles, whereas, the best illuminating gas made from coal, or water gas, rarely exceed twenty-two candles for each five feet burned per hour. Your Philadelphia city gas is rated at from nineteen to twenty candles. Acetylene gas will, therefore, produce twelve and a half times more light if the same quantity be consumed, or one thousand cubic feet of acetylene gas will give you the equivalent in light-



Exact size of Acetylene flame burning ½ cubic foot per hour.



Exact size of ordinary city gas flame burning 5 cubic feet per hour.

ing power of twelve thousand five hundred cubic feet of your city gas; it has, therefore, twelve and a half times the value." These were the words of Willson and Suckert, quoted from their paper before the Franklin Institute, March 17, 1895, and though that was one of

the earliest recorded statements from persons who can be regarded as authoritative, later research has not had occasion to greatly modify their figure. The relative light value of acetylene and illuminating gas is variously stated, often in exaggerated terms, especially in the expressions of those whose chief motive is to sell a machine. But thirteen is a frequent figure now used by good authorities, and the writer considers that, for a conservative and safe figure on which to base any calculations that this paper may call for, one cannot do better than use the ratio set down by the authorities just mentioned, namely, that foot for foot, acetylene has twelve and a half times the illuminating power of city gas. In all such comparisons it is well to remember that acetylene is a *compound*, of invariable composition the world around, wherever it may exist or be prepared, except for occasional, incidental or accidental admixture of other material, whereas coal gas is not a compound, but a *mixture*, of variable proportions, different for every different gas works, though of course possessing an average composition which can be used as a basis of calculation, while the product of individual plants may differ materially from such average.

The comparison of its illuminating power with that of other well known compounds, as made by Lewes, is as follows, all based on five cubic feet per hour of consumption:

1. Methane, 5.2 candles.
2. Ethane, 35.7 candles.
3. Propane, 56.7 candles.
4. Ethylene, 70.0 candles.
5. Butylene, 123.0 candles.
6. Acetylene, 24.0 candles.

This table is of interest because substances (1) to (5) are all constituents of coal gas, in varying proportions. But coal gas, as regards its luminous constituents, consists chiefly of methane, mixed with but little of the other gases in the above table, which possess a higher illuminating effect, and mixed at the same time with large percentages of gaseous matter which has no luminosity whatever. Hence the low average lighting power of coal gas which for Philadelphia city gas was placed, above, at nineteen to twenty candles for five feet per hour. With the modern improved burners for acetylene, the best one-half foot burners should develop twenty-five candle power as against the five foot coal gas burner developing twenty candles. Thus the ratio of twelve and one-half to one is maintained. And though this may be variously stated by interested parties, now high, now low, it is safe to accept, as an entirely unprejudiced basis of calculation, that the highest effects which can be produced from acetylene and coal gas respectively, without the aid of artificial air supply other than that created by the flames themselves, are as twelve and one-half to one.

DANGER.

The possible danger to arise from the introduction of any new and untried commodity, whether a food stuff, an illuminant or any other article of necessity or convenience, should be thoroughly known before any steps are taken.

It seems to the writer that all the dangers in the use of acetylene must classify under one of the following heads:

(a) Danger which may arise from the poisonous action of acetylene in case it should escape through leaks or open burners into the air.

(b) Danger which may arise from breathing air vitiated by the combustion of acetylene in it.

(c) Danger which may arise from explosion.

A few years ago, when the commercial production of carbide was a novelty, most exaggerated accounts of its dangerous character were published in the newspapers and passed from mouth to mouth. Fortunately or unfortunately, about every one who has heard of acetylene, has heard also of its supposed dangerous character. Some would have it dangerously poisonous, others dangerously explosive. No doubt there were some impurities in the earlier specimens of carbide which were placed upon the market, and these caused impurities in the gas, which, whether toxic or otherwise, dangerous in any way or not, modified the character of the first few thousand feet of acetylene used. But, to-day, when we may be reasonably sure of the commercial purity of our carbide, this question is not so serious. The impurities of acetylene will be discussed in a later topic, and now that the first outbursts of the alarmists have died away, we may impartially, seriously and quite thoroughly analyze and inquire into all the possible sources of danger. Let us consider them in the order above suggested.

(a) Danger from Toxic Action. It has been shown that acetylene is far *less* poisonous than the usual illuminating gas sold in our cities. While it might occur to a wag to observe here that it matters little what becomes of the man who intentionally, or otherwise, "blows out the gas," it is still to be said that far less gas can pass through an ordinary acetylene burner, one-half foot, than would pass through an ordinary coal gas burner, five foot, assuming that both are accidentally left fully turned on and gas escaping at full head. So that if the "patient" should quietly breathe the resultant polluted air, allowing, for the sake of argument, that the two gases are of equally poisonous character, which is not true, it would take him ten times as long to get a troublesome dose of acetylene as of coal gas. But it is highly improbable that he would quietly breathe the gas long

enough to do any harm whatever. Acetylene makes its presence known by its peculiar but persistent garlicky odor, which in most cases would be a sufficient safeguard. Again its effects are irritant and annoying rather than somnific, a second important circumstance favoring the probability of the acetylene leak being discovered and stopped.

(b) Danger from Vitiated Air. The combustion of all oils or gases used for illumination, and the respiration of all animals impoverish and pollute the air in an unventilated space, rendering it "close." It has been shown that it is an inherent property of acetylene to offend less in this direction, light for light, than any other illuminating gas. Since the results of burning acetylene are eactly the same in character as when petroleum or coal gas or water gas is used, namely, robbing the air of oxygen, and charging it more or less with carbon dioxide, and since exactly the same charges may fairly be made against oil or coal gas as against acetylene, and to a greater degree, it would be manifestly unfair to acetylene to dwell longer on so remote a possibility of danger.

(c) Danger from Explosion. In case of acetylene, *or any other combustible gas whatever*, two things are necessary for explosion:

1. Admixture with air.
2. Ignition.

The gas must first escape into and mix with the air, and then be ignited or kindled. In no other way can explosion result. Suppose through ignorance or carelessness a gas jet is blown out or left open. As just now stated, half a foot will pass in an hour. Suppose it to be a foot. A room ten feet square and eight high, scarcely more than a closet, is certainly small enough to make a fair illustration. Granted that this room is perfectly gas-tight, a highly improbable condition in itself, but let it be supposed. In just twenty-four hours enough gas will be admitted to charge the air of the room to the lowest explosive limit of three per cent. Still this mixture must find a way to become kindled before an explosion can possibly ensue. And from what was just stated of the irritating, rather than somnific effect of this gas, it is highly improbable that a person would continue to remain in a closed room long enough for danger to arise from the gas escaping out of an open burner. Asphyxiation, in the sense in which we know it as resulting from the respiration of coal gas and stove gas, is entirely unknown to the character of acetylene. But we are not limited to the escaping of gas through open burners; a pipe may split or crack, a connection get pulled apart or something break down about the machine. Very true, but never without revealing the presence of the gas by reason of its penetrating odor, which is indeed a blessing in disguise in such cases. In the event of cracks, defective joints, etc., it is further true, that far less acetylene would

escape in a given time than would be the case with coal gas, because of its greater specific gravity. Distressing in truth are the accounts of accidents caused by the ignition of gaseous mixtures resulting from broken coal gas pipes, but the man who searches for a gas leak with a lighted candle or lamp is of the same type as the man who "did not know it was loaded." There is no remedy for this inherent difficulty, hence no way to remove the danger except by rigidly adhering to the rule that no light shall be taken where gas can be mixed with air. Open flames should on no account be used in the vicinity of acetylene generators or gas holders; neither should a lighted cigar. This is a real danger; the writer makes no attempt to conceal or mitigate it; but it is a danger of which acetylene partakes, together with every other illuminating gas or oil, whatever, share and share alike. It is further true, that explosions of the character under consideration, can scarcely ensue except from gross inattention, ignorance or carelessness, and relatively they should not be so numerous as those arising from coal gas.

Everything considered, though prejudiced against it at the outset, and absolutely and purely disinterested at present, after much careful study and feeling the responsibilty of being called upon to furnish an unbiased opinion in this matter, the writer believes that *the use of acetylene gas for the illumination of rural homes, provided it is generated from good carbide in a first class apparatus, and all reasonable regulations followed, is no more fraught with danger at the present day, than any available method of illumination by gas, or electricity, and less so than the usual employment of petroleum.*

Specific accidents may indeed be cited, but it would be difficult if not impossible to refer to one which was not due to inexcusable ignorance or gross carelessness. One at the Wilmington postoffice in December, 1897, causing the death of an attendant, produced great and widespread consternation. But this catastrophe was traced by official investigation to the fact that gas was allowed to escape in large quantity into the room which contained a lighted jet, as well as a burning furnace. Any other combustible gas would have done the same thing. Nor is acetylene the only offender as regards gas catastrophies. More recently the capitol at Washington has suffered damage to the extent of many thousands of dollars, and valuable public records were lost through an explosion of city gas and the subsequent conflagration. Gas works in various cities have exploded at different times. To-day's New York paper enumerates twenty-five asphyxiations in a little more than one month, December, 1899, by the gas supply of that city, yet it is not proposed to discontinue the use of coal gas. In another column of the same daily is found an exposition of the evils of the abuse of certain valuable drugs, notably cocaine, but it is safe to assume that the employment of cocaine in

surgery will not be abandoned because its irrational use has occasionally produced deleterious results.

IMPURITIES IN ACETYLENE.

With regard to impurities in acetylene, it may first be remarked that all such impurities owe their origin to impurities in the carbide from which it is derived. Impurities of carbide, therefore, claim the first consideration. These may be grouped in two classes:

(a) Those which have no action on water, and

(b) Those which, reacting with water, throw off some gaseous products of the reaction, which remain with the acetylene, rendering it impure.

The former, consisting of such substances as carbon (coke not changed in the furnace), silica, and a few others, since they can with water produce nothing which is added to the resultant gas, are harmless except in so far as they increase the quantity of the residue, and so may be dismissed. The latter, which may impart to the gas, small quantities of impurities, harmless or otherwise, should be looked into. A few years ago when the carbide industry was altogether new, and when the attempt was made to put carbide on the market at something approaching the ridiculously low figure which was first predicted for it, cheap materials were employed, and a poor result secured. It was quite naturally supposed that the cheapest lime and the most worthless coal would answer the purpose. The result was that some very poor carbide was sold and some correspondingly impure acetylene was made. It was soon found that this would not do, the practice was corrected, and at present a specimen of carbide is rarely found which can be said to be dangerously impure. Present practice does, and future practice must insist on purity of material. Good metallurgical coke, the analysis of whose ash shows only the merest traces of sulphur and phosphorus, is easily obtainable. This with a reasonably pure lime yields carbide of great purity and there should be no other made. In fact the quality of carbide has improved and it is reasonable to suppose that it will improve further, or at least, become no worse than at present. Absolutely chemically pure carbide is an industrial impossibility, but the product which is known as "commercially pure" is a very good article. But even as the best available carbide contains some impurity, it is well to see what results may occur in the quality of the acetylene. Phosphorus and sulphur, mostly but not wholly dissipated by the heat of the furnace, appear to a slight extent in the acetyline in the form of minute quantities of phosphoretted hydrogen, PH_3, and sulphuretted hydrogen, H_2S. There may also be small quantities of ammonia, $N\,H_3$, and traces of hydrogen, silicon hydride, and

possibly one or two others of little significance. Analyses of acetylene evolved from certain commercial carbides gave results as shown:

	I.	II.	III.	IV.
Ammonia, per cent., ...	0.09	0.06	0.10	0.07
Phosphoretted hydrogen, per cent., ...	0.03	0.09	0.02	0.06
Sulphuretted hydrogen, per cent., ...	0.08	0.02	0.03	trace
Hydrogen, per cent., ...	0.02	....	....	....
Silicon hydride, per cent., ...	....	trace	trace	....

These are recent analyses from different sources. Of the impurities considered, hydrogen is harmless and may be dismissed. Phosphoretted hydrogen and silicon hydride are self-inflammable and hence would kindle the gas, on exposure to air, if either could be present in considerable quantity. This is not so serious a property as might at first seem, for no kindling could occur until the gas escapes into the air and such ignition, if it ever occurred, could scarcely do harm. Such a thing as kindling the gas within the generator, or while in the pipes, is an impossibility. But the total quantity of these impurities is so very small that the possibility of their ever effecting the ignition of acetylene is an extremely remote one. The instances in which it has ever been claimed that this may have taken place, are so few and rest on such slight evidence, that the writer does not believe them at all. Experiments have conclusively shown that the quantity of either one of these necessary to ignite a body of acetylene gas allowed to flow into the air under most favorable conditions, is so great, as never to be realized, in the writer's opinion, in the practical use of any carbide likely to be found in the market.

Phosphoretted hydrogen is exceedingly poisonous and most deleterious if inhaled. But when we consider that a small percentage of acetylene in air is sufficient to render the air wholly irrespirable, and that only a few hundredths of a per cent. of the poisonous gas could be present in the acetylene at the most, the possible quantities which a person could take into his lungs in this manner are so small that the writer believes that a case of poisoning by this means could not be brought about, even if the attempt were intentially made.

Aside from what has been mentioned, no further damage to persons or property would arise from the the impurities in acetylene even if quantities of it were to escape constantly into the living apartments of our homes. The ammonia and the sulphuretted hydrogen are soluble in water and will to a varying degree be held back in the water of the generator and of the gas holder. The phosphoretted hydrogen is not so and will all enter the pipes. But supposing all three of them, and these are practically the only ones which need to

receive any further attention, should pass through the distributing system and arrive at the burner, what will then become of them? Entering the flame where the other gases are burning, they too, will, for the most part at least, burn also, and the products of their combustion, like the products of combustion of acetylene itself, be thrown out in the air. Let us see what these are:

Phosphoretted hydrogen, in burning, produces phosphoric oxide and water vapor.

Sulphuretted hydrogen produces sulphurous oxide and water vapor.

Ammonia produces free nitrogen and water vapor.

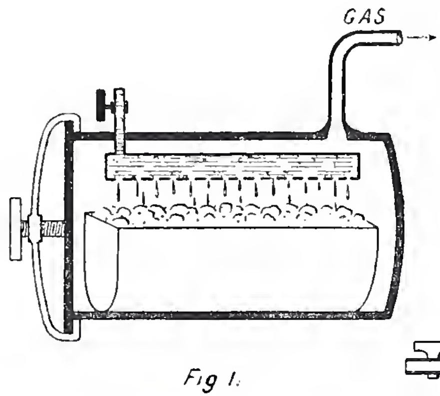
Of these products the nitrogen and water vapor may both be disregarded as entirely harmless. The sulphurous oxide, remaining for a time in the air, may become converted into sulphuric acid and this may be objectionable to health, and especially deleterious to book bindings, draperies, etc. Phosphoric oxide is without a question objectionable in the air and may produce poisonous effects of a serious nature if inhaled in considerable quantity. It is therefore not to be questioned that these impurities in acetylene should be removed from the gas before it arrives at the burner, if they can be present in considerable quantity. Ammonia and hydrogen sulphide are always present in crude coal gas and are removed in the purifying process to which that commodity is always submitted, yet it may be detectable in minute quantity in most city gas supplies. The question is one of quantity of impurity and whether we can afford to overlook it because of its very small dimensions. Purification is discussed in a later topic, but here it may be well to keep before us the fact that the purity of acetylene goes hand in hand with the purity of carbide, and just as prevention is better than cure, so to use only an excellent quality of carbide, thus avoiding impurities, is clearly better than to use a poorer grade, assuming the formation of these impurities and then to set about to remove them. Enough has been said of impurities arising from carbide, but a word may perhaps be added on the results of overheating.

In the generation of acetylene, enormous chemical affinity is displayed between the calcium in the carbide and the oxygen in the water, and as in all such chemical changes, a great quantity of heat is evolved. According to the method of bringing the water and the carbide together, this heat may be localized so as to be harmful, or so distributed as to cause no harm. In the experiment of dropping a fragment of carbide into a tumbler of water, the heat of the reaction is so absorbed by the relatively large body of water, that overheating does not occur at any point. But reverse these conditions by allowing water, in limited quantity, drop dy drop, to fall on to a lump of carbide and you bring about the overheating of the resultant gas, its

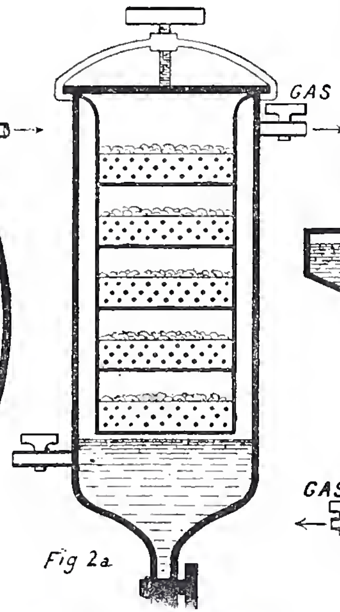
conversion to some extent into oily matters, polymerization, and even into a tar, so that samples of carbide which have been thus treated in an experimental way, have come out of the experiment smeared with a yellow, dirty, tarry mass, which shows evidence at once of overheating in the gas making process, resultant loss of acetylene, and consequent oily matters formed which may cause trouble when the gas laden with them comes along to the burners, causing the latter to clog and refuse to properly operate. These products of overheating are therefore of such a nature as to call for discussion in this section, although they are not impurities in the ordinary sense. They do not pollute the air nor endanger health in any way, but as they cause inconvenience and trouble with the burners, they must not be ignored. Since too great heat, and this alone, causes their formation, the rational remedy is to prevent their production by avoiding high heat at the moment of generation. The remedy is prevention. The means of prevention is cool generation.

COOL GENERATION.

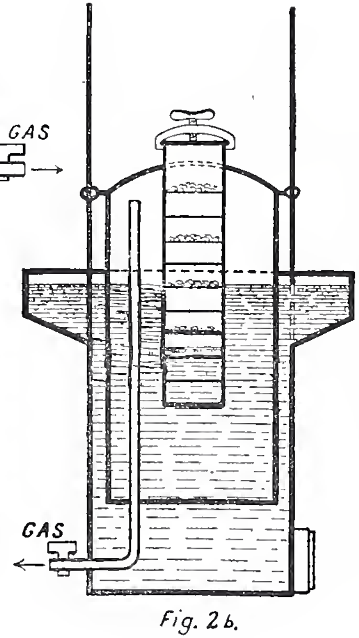
It is essential to emphasize the matter of cool generation as one of the utmost importance in acetylene manufacture. The function of the generator is in principle a simple one. It has to provide for the bringing together of the water and the carbide, wash and purify the gas, store it to such extent as may be necessary, and deliver it to the pipes for distribution. The more nearly the generator conforms to the simple experiment of dropping a little carbide into a large volume of water, the more efficiently will the heat be distributed and the more perfectly will "cool generation" be accomplished. The other extreme is where a little water is allowed to drip upon an excess of carbide, as in the second experiment; heat is localized instead of distributed, becoming excessive at the point of most rapid generation. Thus the opposite of cool generation will be secured, gas once formed will be used up in making the heat products, benzene, styrolene, anthracene, etc.; a lower yield than the correct one will be secured from the carbide, lower candle power will also result, and the tarry products cause carbonizing of the burners resulting in their becoming choked and smoky, three items of great wastefulness, to say nothing of the annoyance and inconvenience. Foremost among the requirements for a good generator is, therefore, the one which demands that heat shall be avoided as much as possible. Excessive overheating is detected by the appearance of the lime left after the gas generation. If the residium is discolored yellow or brown, serious overheating has taken place, for this lime sludge should be essentially white. Tarry deposits in the residue indicate a still greater degree of overheating. It is well to remember in this con-



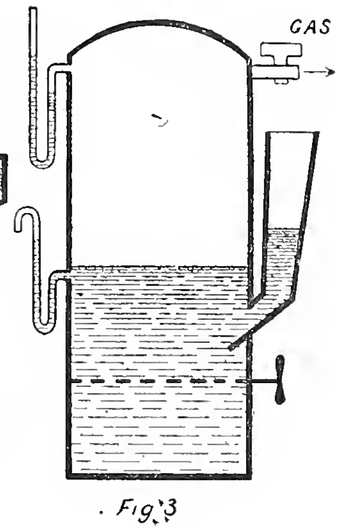
Type I (*a*).



Type II (*a*).



Type II (*b*).



Type III.

nection that the most prolific cause of overheating is to overwork the generator. If a generator is calculated for ten burners and is called upon to make gas for twenty the result is sure to be excessive heat production.

LIME DUST AND PIPE CLOGGING.

There is another foreign substance, not to be looked upon as an impurity in acetylene, yet one which, under improper conditions, is sometimes mechanically carried along from the generator to the distributing system; this substance is lime dust or carbide dust. Its occurrence is an evil which may cause damage unless averted. It however can only arise when dry, hot carbide is attacked by small charges of water. A gas thus charged with dust, arising at high heat from dry carbide may carry with it very considerable quantities of a very fine dust, which if it gets into pipes is certain to cause the keys to "set," or become fixed, and may even clog the pipes, causing objectionable if not dangerous stoppage in the flow of the gas.

A few years since this trouble was prominent among the machines then on the market and certain acetylene outfits were given up in disgust because of this conspicuous objection. But the difficulty is not at all an inherent one and at the present day there is so little excuse for it that it is scarcely known. The method of dropping small charges of carbide into water, practically does away with it, and a gas which is charged with dust will not remain so if thoroughly washed by being compelled to rise in fine streams, through a few inches of water, a contrivance for which can be readily made a part of any machine. Dust arresters in which the gas is freed from dust by being caused to pass through chambers containing cotton, etc., are also provided, with some forms of generators, and occasionally the gas is passed through fine bolting silk, for the same purpose.

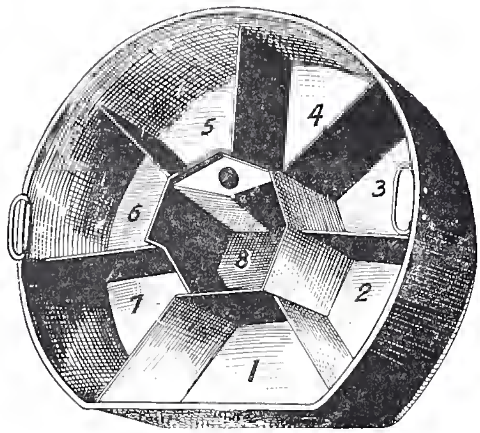
The question, "Do you ever have clogging of pipes by lime or any other solid matter?" was asked of some one hundred and seventy-five manufacturers of acetylene generators. No one admitted such deposits; most responses were emphatic in their denial; several added that they had repeatedly taken down pipes after some years of use, to search for such material, and found none.

TYPES OF GENERATORS.

Thus far only two general methods of bringing water and carbide together have been mentioned in this paper, viz: "Carbide into water," and "water on carbide." In practice is found one additional method which partakes partly of one and partly of the other of the two general methods, but these three types embrace all of the machines on the market in this country. A glance at the cut will

show the types to be explained below, but it is not always to be expected that a machine will exhibit as simple outlines and detail as do the cuts, nor always from outward appearance, to be easily referable to its type.

In machines of type I, water is sprayed, dripped or allowed to slowly flow upon carbide contained in a receptacle so arranged that the accumulating gas stops the flow of the water. These machines fall into two sub-divisions, (*a*) those in which carbide is contained in large pans or baskets, and water is added to considerable carbide at once, these are known as "spray," or "drip" machines; (*a*) those in which the pans are sub-divided, water added to a limited amount of carbide in a small compartment first, and each compartment overflowed before the water passes to the next compartment. This is called the "overflow" or "flood" system. The above series of cuts



Divided Pan, Type I (*b*).

exhibits only sub-division (*a*) of type I. To show how one manufacturer has worked out the divided pan system, reference is made to the above figure which shows a common idea in "overflow" machines. Water attacking carbide first in compartment 1, overflows to compartment 2, where it finds a fresh supply of carbide, exhausts and floods the latter before it can pass on to 3, and so on till all the cells are flooded in rotation, then the advancing water passes from cell 8 to another pan below.

In machines of type II, water in quantity comes in contact with carbide in quantity, either (*a*) by allowing the water to rise to a basket filled with carbide, or (*b*) by permitting such a basket to be lowered into water, until generation commences. In machines of type II (*b*) the accumulation of gas causes the water to recede from the carbide, thus stopping the generation; such an apparatus is called a "recession" or "displacement" machine. Type II (*b*), known as "dip" machines, have practically gone out of use. There were a few machines in which a carbide basket was attached to the dome of the

bell of the gasometer on the inside. As the bell in such an apparatus falls the carbide dips in the water, generating gas, which in turn raises the bell, but these machines are open to many and serious objections, and are now practically obsolete.

In machines of type III, carbide is dropped or plunged into an excess of water, hence the name "drop" or "plunger" generators.

Of whatever type, every generator must have sufficient holder capacity to provide for all generation in excess of use at any time, including what is called "after generation," which is the amount of gas generated after the lights are turned off, but before gas evolution can entirely cease. This is usually accomplished by the well known bell gas holder. There are other devices to accomplish the same purpose, but the bell is so common as to be almost universally present in the machines available in this country. Acetylene generators are also usually automatic, that is, aside from periodical care in cleaning and recharging, they are designed to need no attention. They must provide for the automatic evolution of gas as fast as gas is drawn at the burners, and to cut off the evolution, also automatically, so soon as practicable after consumption ceases. Large installations, such as for village lighting, extensive factories, etc., might properly be so constructed as to call for constant attendance, at least during the hours of greatest use; but small plants, such as are employed for household use, ought not to demand attendance more than at the rate of a few minutes daily, in other words, must automatically supply water to carbide, or carbide to water, as the case may be, during the time in which gas is being generated. It would of course be possible to generate at certain intervals when the time of an attendant could be given to this duty, supplying carbide by hand to the water, and storing enough gas to last for a day or two. But this method would demand unnecessarily large gasometers, which would be bulky, expensive and difficult to place, hence this method is nowhere in vogue for small installations, the automatic machines being everywhere preferred, and as the aim of this paper is to discuss only such apparatus as is suitable for country homes, whenever generators are hereafter mentioned in this report, automatic ones will be intended.

Sometimes we see generators classified as "wet" and "dry," or we observe that they are said to be based on the "wet system," or the "dry system." This is wholly a matter of residuum and has nothing to do with the real type of generator explained above. In all type III generators the residuum is removed wet, as a matter of course, so is it also in all of type 1 (*b*), and probably in all of type II. But certain "spray" machines or "dip" machines are so adjusted that only enough water shall be added to convert the carbide into a *dry* residue, which is removed in this dry form and gives the name to this

division or group of machines. Some are provided with a grate or shaker, so arranged that after a mass of carbide has received a considerable spraying, it may be shaken like a coal stove, the spent lime falling through the grate to be removed like coal ashes while the unconsumed carbide, remaining on the grate, is in so much the better condition to receive further sprinkling with water. It is charged against the "dry" machines that they cause lime or carbide dust in the pipes, that they are wasteful because unused carbide may be carried away with the ashes, and that the residue possesses too much odor, owing to the unspent carbide. On the other hand, it is claimed against the "wet" machines that the residuum is sloppy and untidy to handle, and that the removal of the water carries away gas in solution.

Generators of type I (*a*) are liable to heat excessively, to generate steam which may perhaps be carried on into the pipes, and to throw out particles of very fine lime dust which may also find its way into the distributing system, and result in clogging the pipes and jets. If these faults are all true, together with the evils of overheating, already explained, generators of this type must deserve general condemnation. Probably this explains the present very obvious movement towards sub-division (*b*) of type I, for certainly a number of apparatus formerly of type I (*a*) have been so modified by the introduction of sub-divided carbide holders as now to classify as of type 1 (*b*) and are using water enough to flood the carbide and thus have become "overflow" or "flood" machines. These are probably open to less objection than the sprinklers.

Generators of type II may vary greatly in their practical operation. If water comes up to the carbide, generates vigorously for a short time, and then recedes quite away, the carbide may become heated to a glowing temperature and by reason of this excessive heat do great damage. But by good mechanical ingenuity this has been avoided in some generators so that the water advances only very slowly and maintains a nearly constant level, allowing the carbide less opportunity to become incandescent.

In generators of type III, a charge of carbide is plunged at once under the surface of a large amount of water and is not subsequently withdrawn. Hence a temperature greater than two hundred and twelve degrees Fahrenheit, the boiling point of water, can not be reached in this type of generator, and in fact, owing to the great heat absorbing power of water, if small charges are used at a time, the temperature of the water should not and generally does not rise through more than a very few degrees. It is urged against these machines, first, that the carbide may become buried in a protective coating of pasty lime sludge at the bottom of the tank, and so surrounded as not to be more than superficially attacked by the water,

and hence carried out unused and wasted in the residuum, or left to generate gas at the wrong time and thus cause damage; and, second that the mechanisms for bringing carbide into water are complicated, clumsy, and likely to get out of order. The former difficulty is obviated by the use of some sort of a false bottom or grate or other carbide container which shall hold the carbide in place while the water acts upon it and thus prevents its burial in lime sludge. The latter difficulty is a more valid one. To be sure, it is perfectly clear that water submits to regulation by mechanical means more readily than a solid. A cock or valve so constructed as to feed water at any desired rate, be easily and automatically started, stopped or regulated, is one of the simplest things possible in mechanics; while to devise a mechanism to regulate the feed of a solid substance is not so easy a problem to solve. In fact, it was for a time declared to be impossible to construct a mechanism which should automatically feed carbide in coarse or fine lumps into water as it should be needed, and at the same time be simple and not likely to get out of order. To see how well this practical problem has been solved, one has but to look at the best type III machines which are on the market to-day. An impartial and disinterested observer can hardly fail to conclude that the mechanism for type III machines has been just as satisfactorily worked out as for type I or II.

Of whatever type it may be, a good generator, such as can be recommended to rural homes in Pennsylvania, must be possessed of certain qualities which will be conceded by all:

(1) It must allow no possibility of the existence of an explosive mixture in any of its parts at any time. It is not enough to argue that a mixture, even if it exists, can not be exploded unless kindled. It is necessary to demand that a dangerous mixture can at no time be formed even if the machine is tampered with by an ignorant person. The perfect machine must be so constructed that it shall be impossible at any time under any circumstances to blow it up. It must be "fool-proof."

(2) It must ensure cool generation. Since this is a relative term, all machines being heated somewhat during the generation of gas, this amounts to saying that a machine must heat but little. A pound of carbide decomposed by water develops the same amount of heat under all circumstances, but that heat can be allowed to increase locally to a high point, or it can be equalized by water so that no part of the material becomes heated enough to do damage.

(3) It must be well constructed. A good generator does not need, perhaps, to be "built like a watch," but it should be solid, substantial, of good material. No light weight, half price metal, likely to rust through and cause leakage and resultant gas mixtures, should be tolerated. It should be built like a plough, or like a steam

engine, of the best material adapted to the purpose. It should be built for service, to last and not simply to sell. There are "tin can" generators enough on the market, and now and then one may receive the endorsement of sensible people, or even perhaps of the Underwriters, but they are to be avoided as unsafe and unreliable. See that your generator is as well made as your farm implements.

(4) It must be simple. The more complicated the machine the sooner it will get out of order. Before purchasing, see a drawing of the machine you plan to purchase, and be shy of the man who can not give you a blue print. Understand your generator. Know what is inside of it and beware of a plant, however attractive its exterior, whose interior is filled with pipes and tubes, valves and diaphragms, whose functions you do not perfectly understand. If a complicated mechanism is employed to perform what seems to you a simple duty, rely upon your own common sense and look further till you find a perfectly simple but strong mechanism to perform the work of automatically making your gas. There are plenty of them and you can afford to meet the price of the machine which is least likely to call for repair next season.

(5) It should create no considerable pressure in any of its parts. Low and uniform pressure at the jet is no guarantee of low and uniform pressure in all parts of the machine. It is important to be sure of this point. More than three or four pounds pressure at any point may be a source of danger; more than a few ounces is wholly unnecessary.

(6) It should be capable of being cleaned and recharged, and receiving all other necessary attention, without loss of gas, first for economy's sake, but more particularly to avoid filling the house with a disagreeable odor. There is no need of any perceptible odor about the machine, or in the house and the better machines successfully guard against this nuisance.

(7) It should require little attention. All machines have to be emptied and recharged periodically; but the more this process is simplified and the more quickly it can be accomplished the better.

(8) It should be provided with a suitable indicator to designate how low the charge is in order that the refilling may be done in good season. A generator which can by any reasonable possibility leave the household, without warning, plunged in darkness, is not to be tolerated.

(9) It should completely use up the carbide, generating the maximum amount of gas.

(10) It should have a purifier.

As to selection of type of generator, there are good generators of all the types, and under local conditions it may not be always an easy matter to select the type. It may possibly be sometimes rather a question of getting the best available machine, regardless of the

type. But if the fittest survives, the opinion of the writer is that the "carbide into water" machines will be the generators of the future. The famous Moissan, French savant and chemist, wrote as long ago as December, 1896, as follows:

"The ideal apparatus, which I think does not yet exist, consists in a gas holder containing an excess of water into which a fragment of carbide of known weight falls automatically at the desired moment. The weight of this carbide should be such that it will fill the gas holder with gas without producing an excess. Moreover this carbide should not fall till the moment when the gas holder is nearly empty."

And Professor Lewes, English chemist and illuminating gas authority, wrote early in 1898:

"The generators of the third class (type III) are undoubtedly the best, as, with the water kept in excess, it is impossible for the temperature to rise above the boiling point of water, and under all conditions, this class of generators yields the purest gas, as the acetylene, having to bubble through the lime water, formed in the generator, is washed free from most of its impurities." Also, still referring to generators of type III, "With a properly arranged tank the temperature never exceeds the air temperature by more than a few degrees. Under these conditions, the absence of polymerization and the washing of the nascent and finely divided bubbles of gas by the lime water, in the generator, yields acetylene of a degree of purity unapproached in any other form of apparatus."

In following the development of generators in this country up to the end of 1899, the writer sees no reason to be swerved from the opinion which the above authorities would promote. If any thing is to be learned from the experience of France and England, as well as of Germany, whose people lead us in applied, no less than in theoretical chemistry, it must be agreed that the "carbide into water" principle is the only scientifically satisfactory one.

SUPPLY OF CARBIDE.

The use of acetylene rose into general popularity with such amazing rapidity, that during last winter, 1898-1899, there was a scarcity of carbide in the United States, and some people less provident than others, who failed to place their orders early, were not able to secure a supply. Since then, however, the facilities for manufacture have become largely increased and it is not probable that there will be a scarcity of this material for any length of time in any season hereafter. The manufacture of carbide has steadily increased all over the globe, and there are now carbide manufacturing plants in active operation in all civilized countries, including Spain. The great plant

erected some years ago at Niagara Falls was many times enlarged and large sums of money were expended in tearing down old apparatus and building up new which should be more satisfactory in its results. Further, a new plant of enormous proportions, said to consume twenty-five thousand electrical horse power and to put out one hundred tons of carbide per day, has been constructed there and is now operating. These plants, with the one at Sault Ste. Marie, Michigan, will now be able to supply the demand for some time to come. For a year previous to June 1, 1899, over seven thousand tons of carbide were sold in the United States alone. For the year following June 1, 1899, provision is made to manufacture ten times as much carbide as in the previous year. The carbide industry is no longer in its infancy, but is developed and organized and under control of strong and responsible companies which sell a guaranteed product.

TRANSPORTATION AND STORAGE OF CARBIDE.

Carbide must be packed as soon as made, in some sort of hermetically sealed containers to preserve it from the rapidly deteriorating action of moisture. When dry, it is a perfectly harmless substance being solid and incombustible. Its only dangerous attributes can be developed solely by contact with water. Well packed, it is as safe to store or transport as other ordinary commodities and probably safer than many inflammable things as wood, coal, cotton, etc. If the building in which it is stored should burn, unbroken packages will go through the fire unharmed, so also would loose lumps if packages break, except for the circumstance that considerate firemen usually play plenty of water upon them, compelling them to generate gas, which in turn burns, and contributes to the conflagration. But in itself there is nothing about carbide to render it a specially dangerous substance. Certain false impressions were disseminated very early in its history, about carbide, and have by their persistence, much handicapped this deserving though youthful aspirant for honors in the field of industry.

As the London Chemical Trade Journal put it, "All the trouble has, we think, undoubtedly arisen through a certain amount of misunderstanding and confusion of ideas. It would seem that the fire insurance people have not been quite clear as to the difference in the nature of calcium carbide and acetylene gas. Knowing that the one generally had something to do with the other, they have evidently thought they were pretty much of a muchness, and made no distinction."

Carbide is packed for delivery to consumers in air tight cylindrical metal cases, protected by outer cases of wood or iron, frequently sheet iron cylinders with wooden heads. This outer case prevents the

denting or puncturing of the inner container during handling or transportation.

INSURANCE REGULATIONS.

It would lead beyond the intended limits of this report, to enter upon insurance regulations which have existed in this or other countries, but which are not now in force. Those in operation in this country at the present time, annulling as of course they do, all previous rules, are alone of interest to us. All insurance regulations affecting carbide and acetylene should be based on the most accurate scientific knowledge of the gas and the method of its production. The Underwriters have with great care worked out the regulations affecting insurance companies in this territory. On the 27th of December, 1898, the National Board of Fire Underwriters adopted the following rules, and the same have since been approved and adopted by all, or essentially all, of the Associations and Boards of Fire Underwriters in the United States:

ACETYLENE GAS RULES.

National Board Rules Governing Construction of Standard Apparatus.

The use of liquid Acetylene or gas generated therefrom is absolutely prohibited.

The permission to generate and use Acetylene in insured premises shall be subject to the following rules:

Apparatus.

It is desirable that all Acetylene Gas machines shall be installed outside of the building insured, but special permission may be granted in the discretion of tariff associations having jurisdiction to install machines inside the building under special circumstances, such permission to be given in writing and shall be subject to the following rules:

1. Must be made of iron or steel, and in a manner and of material to insure stability and durability.

2. Must have sufficient carbide capacity to supply the full number of burners during the maximum lighting period.

NOTE.—This rule removes the necessity of recharging at improper hours. Burners almost invariably consume more gas than their rated capacity and carbide is not of staple purity, therefore there should be an assurance of a sufficient quantity to last as long as light is needed. Another important feature is that in some establishments burners are called upon for a much longer period of lighting than in others, which requires a generator of greater gas-producing capacity.

3. Must be uniform and automatically regulated in its action, producing gas only as immediate consumption demands, and so designed that gas is generated without excessive heating at all stages of the process.

NOTE.—This rule is necessary, because the presence of excessive heat tends to change the chemical character of the gas and may even cause its ignition.

4. Apparatus not requiring pressure regulators must be so arranged that the gas pressure can not exceed thirty tenths inches water column (three inches).

5. Must be provided with an escape pipe which will operate in case of the over-production of gas, and also an attachment acting as an escape or relief in case of abnormal pressure in the machine, and which will carry such excess gas through an escape pipe of at least three-quarter inch internal diameter to a suitable point outside of building, discharging at least twelve feet above ground level and provided with an approved hood.

NOTE.—Both the above safety vents may be connected with the same escape pipe.

6. Apparatus requiring pressure regulator must be so arranged that the gas pressure can not exceed three pounds to the square inch. Such apparatus must be provided with additional safety blow-off attachment located between the pressure regulator and the service pipes and discharging to the outer air, the same as provided for in Rule 5.

NOTE.—This is intended to prevent the possibility of undue pressure of gas in the service pipe by failure of the pressure regulator.

7. Must be so arranged that when being charged the back flow of gas from the holder will be automatically prevented, or so arranged that it is impossible to charge the apparatus without first closing the supply pipe to holder, or to other generating chambers, if any.

NOTE.—This is intended to prevent the dangerous escape of gas.

8. Must be so arranged as to contain the minimum amount of air when first started or recharged, and no device or attachment facilitating or permitting mixture of air with the gas, prior to consumption, except at the burners, shall be allowed.

NOTE.—Owing to the explosive properties of Acetylene mixed with air, machines should be so designed that such mixtures are impossible.

9. No valves or pet-cocks opening into the room from gas-holding part or parts, the drainage of which will allow an escape of gas, shall be permitted; and the condensation from all parts of the apparatus must be automatically removed without the use of valves or mechanical working parts.

NOTE.—Such valves and pet-cocks are not essential; their presence increases the possibility of leakage. The automatic removal of condensation from the apparatus is essential to the safe working of the machine.

10. The water supply to the generator must be so arranged that gas will be generated long enough in advance of the exhaustion of the supply already in the gas-holder to allow of the using of all lights without exhausting such supply.

NOTE.—This provides for the continuous working of the apparatus under all conditions of water feed and carbide charge, and it obviates the extinction of lights through intermittent action of the machine.

11. No carbide chamber of over twenty-five pounds capacity shall be allowed in any machine where the water is introduced in small quantities or where the contact of water with carbide is intermittent.

NOTE.—This tends to reduce the danger of overheating and provides for the division of the carbide charges in machines of these types of large capacity.

12. Generator must be connected with the gas-holder in such manner that it will, at all times, give open connection either to the gas-holder or to the blow-off pipe into the outer air.

NOTE.—This prevents dangerous pressure within or the escape of gas from generating chamber.

13. Must be so designed that the residuum will not clog or affect the working of the machine and can conveniently be handled and removed.

14. Covers to generators must be provided with secure fastenings to hold them properly in place, and those relying on a water seal must be submerged in at least twelve inches of water. Water seal chambers for covers depending on a water seal must be one and one-half inches wide and fifteen inches deep, excepting those depending upon the filling of the seal chambers for the generation of gas, where nine inches will be sufficient.

15. Holder must be of sufficient capacity to contain all gas generated after all lights have been extinguished.

NOTE.—If the holder is too small and blows off frequently after lights are extinguished there is a waste of gas. This may suggest improper working of the apparatus and encourage tampering.

16. The bell portion must be provided with a substantial guide to its upward movement, center guide preferred, and a stop acting about one inch above the blow-off point.

NOTE.—This tends to insure the proper action of the bell and decreases the liability of escaping gas.

17. A space of at least three-quarters of an inch must be allowed between the sides of the tank and the bell.

18. All water seals must be so arranged that the water level may be readily seen and maintained.

19. Gas-holders constructed upon the gasometer principle must be so arranged that when the gas bell is filled to its maximum, its lip or

lower edge shall at all times be submerged in at least nine inches of water.

20. The supply of water to the generator for generating purposes shall not be taken from the water seal of any gas-holder constructed on the gasometer principle.

NOTE.—This provides for the retention of the proper level of water in the generator.

21. The apparatus shall be capable of withstanding fire from outside causes without falling apart or allowing the escape of gas in volume.

NOTE.—This prevents the use of joints in the apparatus relying entirely upon solder.

22. Gage glasses, the breakage of which would allow escape of gas, shall not be permitted.

23. Where purifiers are installed, they must conform to the general rules for the construction of other apparatus and allow the free passage of gas.

24. The use of mercury seals is prohibited.

NOTE.—Mercury has been found unreliable as a seal in Acetylene apparatus.

25. Construction must be such that liquid seals shall not become thickened by the deposit of lime or other foreign matter.

26. Apparatus must be constructed so that accidental syphoning of the water is impossible.

27. Flexible tubing, swing joints, packed unions, springs, chains, pulleys, stuffing boxes and lead or fusible piping must not be used on apparatus, except where the failure of the part will not vitally affect the working or the safety of the machine.

28. There shall be plainly marked on each machine the maximum number of lights it is designed to supply and the amount of carbide necessary for a single charge.

To be approved, Acetylene Generators must conform to the foregoing standard, and plans and specifications in detail of such apparatus must be submitted to the insurance organization having jurisdiction over the territory in which such apparatus is to be installed, for approval by an inspector duly authorized by the .... Association, with whom a copy of such plans and specifications must be filed. If the plans are approved, a special examination of the Generating Apparatus will be made at the expense of the applicant, and if it is found to be in compliance with the standard, a certificate of approval will be issued.

Calcium Carbide.

1. In no case shall Calcium Carbide be stored in bulk.

2. Calcium Carbide must be packed in screwed-top, water-tight metal packages, having all seams lock-jointed and soldered. They shall contain not over one hundred and twenty-five pounds of Carbide, and each package must be conspicuously marked "CALCIUM CARBIDE, KEEP DRY." The packages must be of sufficient strength to insure the handling of the same without rupture, and they must be kept under cover at all times.

Indorsement for Use of Acetylene Gas.

In consideration of the following warranties on the part of the assured, permission is hereby granted to generate and use Acetylene Gas on the premises described in this policy, using a .... Acetylene Gas Machine, manufactured by .... at .... when the same is installed in accordance with the rules and regulations of the National Board of Fire Underwriters, and adopted and promulgated by the .... Association.

Warranted.

That the generator shall be charged, and Calcium Carbide handled by daylight only.

That no direct fireheat or artificial light shall be allowed in the room containing the apparatus.

That no Calcium Carbide shall be kept in the building where this policy covers.

That no greater number of lights shall be installed than the maximum for which the machine is rated.

That no change shall be made in the installation without the written consent of this company indorsed hereon.

Attached to and made a part of Policy No. .... of the .... Insurance Company, of ....

The use of Liquid Acetylene or Gas generated therefrom, on the premises described herein, is absolutely prohibited.

Cautions.

Calcium Carbide should be kept in water-tight metal cans, by itself, outside of any insured building, under lock and key and where it is *not* exposed to the weather.

A regular time should be set aside for attending to and charging the apparatus during *daylight* hours only.

In charging generating chambers clean all residuum carefully from

the containers and remove it at once from the building. Separate the unexhausted Carbide if any from the mass and return it to the container, adding new Carbide as required. Be careful never to fill container *over* half full, as it is important to allow for the swelling of Carbide when it comes in contact with the water.

Never place Carbide into the containers until all residuum has been carefully removed.

Water tanks and water seals must always be kept filled with clean water.

Where apparatus is not intended for use throughout the year, all water must be removed at the end of the season.

Never use a lighted match, lamp, candle or any open light near the machine.

Prominent features in the above rules, to which attention is here called are:

(1) Use of liquefied acetylene or gas generated therefrom is absolutely prohibited.

(2) Pressure within apparatus is limited to three pounds per square inch.

(3) No direct fire heat or artificial light is permitted in the room containing the generator.

(4) No carbide is to be stored in insured buildings.

Of these the first three are manifestly right, important and proper. Number four seems to the writer to be unnecessarily rigid, but it is of course well to be on the safe side. This regulation works some little hardship, and may perhaps in the near future be amended in the direction of greater leniency.

While it may be that these rules are not the best that could be devised in every particular, it is true of them that they were worked out with exceeding great care, after prolonged consultation of the expert engineers of the several Underwriters' associations of the United States. Some concessions had to be made before all the details were reached, but the very beneficial result has been attained that practically uniform regulations are in force throughout the country. If it be charged, as is done in some quarters, that it is still easy for an occasional inferior and unsafe machine of the "tin can" type to receive the approval of the Underwriters, answer may be made that the system, nevertheless, does rule out a large number of machines as not complying with the requirements. An "Index to Acetylene Reports," issued by the Underwriters' Bureau of Fire Protection Engineering, of Chicago, in October, 1899, shows that of one hundred and seventy-three machines inspected to that date, sixty-seven had been refused approval. The public has thus been spared the danger which would have arisen from the unrestricted use of

the thirty-three per cent. of the different makes of machines which failed to pass the inspection. There are also a multitude of others which probably have never reached the inspection board because makers of these machines are conscious of their defects. It is still further true that of the one hundred and six generators approved by the above Board, many, probably a majority, perhaps nearly all, failed to receive the official approval on first appearance and only did secure it after making repeated improvements, at the suggestion of the Board. Underwriters' Board work may not be disinterested, but it is directed in the line of the common good, and aims at minimizing the danger to fire; it is the best safeguard we have. The writer can not fail to include in his advice to owners of country residences, *to purchase only such machinery as have been approved in advance by the Underwriters.* There are plenty of such.

The Underwriters' Association of the Middle Department, with headquarters in Philadelphia, has jurisdiction over a large territory in which is included the State of Pennsylvania. This Association does not maintain a laboratory for the thorough examination of acetylene apparatus, but it is the intention of the Middle Department to accept any machine which has met the approval of the New England Insurance Exchange at Boston, and the Underwriters' Bureau of Fire Protection Engineering at Chicago, both of which maintain plants for such tests, provided that the same has been examined and approved since the National Board rules were promulgated. The Middle Department also publishes a list of machines which have received its official approval, and revises this list from time to time. The latest available issue of this document will be used in revising the section of this report dealing with "Available Approved Generators," at the last moment before going to press. The lists which will be given in this report can not include all the good machines made. Such an enumeration is impossible. Without question there are excellent machines in the hands of Underwriters' Associations, for investigation with a view towards approval, which have not yet passed through the tests, and which without doubt will be accepted and approved later on. Such machines can not be included in this report, but in justice to all, mention will be made of all approved machines of which any knowledge can be secured up to the date of publication, with all the facts about each which have been gathered at some considerable pains, and by means of a voluminous correspondence extending over several months. Persons investigating the matter may secure later information than this report offers by addressing the Underwriters.

GENERATORS AVAILABLE.

Since Pennsylvania, outside of the large cities, comes within the territory of the Middle Department, it is well to first refer to machines approved by that Department, any one of which can be installed and used within insured premises if desired, without addition to the cost of insurance, provided all the regulations are complied with.

The language of the official circular of the Middle Department is: "Approval has been granted for the following acetylene gas generators (only when manufactured by the parties named) as being of satisfactory construction, and permission for their use may be given when installed according to requirements." Then follows the list of approved machines, names and addresses of the manufacturers and dates of approval.

The information afforded by this circular is below expanded by inserting such additional facts as have been learned in each case, and this information has been derived from all possible sources. The circulars and other printed matter of the manufacturers furnish certain facts which are reliable, but as no manufacturer has yet been found who does not consider his machine the best on the market, other sources of information have been used as well. The reports of the Underwriters have been carefully studied; as many different machines as possible have been seen by the writer and inspected while in active operation; also many users of machines of different makes have been visited, or written to, and interrogated as exhaustively as possible. In November a circular was sent to all known manufacturers asking some thirty questions, and complete answers to these have been received in the majority of cases. They are valued as expressing the experience of people who have had most to do with acetylene illumination and are naturally to be taken with some confidence when they speak of general matters concerning acetylene, but with caution when they speak in exaggerated terms of the virtues of their own machines. It has seemed proper to include below the maker's statement of cost of a thirty-light plant (or nearest size to thirty-light made), also of numbers of machines in use where these data have been given. It will be also understood that the "Claims of Manufacturers" are quoted in their own terms, and that the writer of this report disclaims all responsibility for the correctness of these claims.

It may be remarked here, too, that the Middle Department in its last circular dated November 21, 1899, has included quite a number of machines, doubtless in accordance with its policy of approving all which have been passed by the Chicago Bureau since the promulgation of the National Board rules; but this action includes a number

of firms which seem to be no longer doing business. Still as the Middle Department circular includes them, this report can do no less, but in cases where repeated letters, at intervals of two or three weeks, have brought no replies, the following list will make note of that fact. Likewise if it has been learned from any reliable source that certain firms have ceased to manufacture, this information will also be noted.

The approved machines are:

1. The "ABNER."
Manufactured by Henry Giessel & Co.,
43 Franklin St., Chicago, Ill.
Approved September 19, 1899.

Type III, "drop." Carbide placed in cups.
Residuum drawn off *wet* through large gate.
Indicator shows when recharging is needed.
About twenty-five machines in use; none in Pennsylvania.
List price of thirty-light plant, $135.00.
Claims of Manufacturers: simplicity; economy; no heat; no rubber gaskets; no stuffing boxes; cannot be overcharged; no gas valves; small floor space; easily cleaned and refilled; better gas from carbide; no over-production of gas, etc.

2. The "ACETOGEN."
Manufactured by F. Cortez Wilson & Co.,
239 & 241 Lake St., Chicago, Ill.,
Approved February 21, 1899.

Type II (*a*), "recession."
Residuum removed *wet* in a drawer which must be taken out before fresh carbide is put in the generator.
No thirty-light size made. A twenty-light machine costs $90.00, or a forty-light machine costs $135.00, f. o. b. Chicago.
Claims of Manufacturers: fool-proof; economical; simple; safe.

3. The "ACME."
Manufactured by The Acme Generator Company,
Waseca, Minn.
Approved November 21, 1899.

Type I (*b*), "overflow."
No response to questions.

4. The "ANGELL."
Manufactured by Edwin R. Angell,
Derry, N. H.
Approved June 20, 1899.

Type I (*b*), "overflow." Water in charges is poured on to carbide, dry at first, followed by flooding the generator.

Residuum removed *wet*, detaching generator and carrying it out to be emptied.

Indicator shows when recharging is necessary.

About fifteen machines in use; none in Pennsylvania.

Price of thirty-light plant, $90.00.

Claims of Manufacturer: least possible amount of air in gas; no waste of gas; no odor; all carbide utilized; little labor in attendance; continuous use with interrupting lights, etc.

5. The "AURORA."

Manufactured by the Aurora Standard Light Company,
103 State St., Boston, Mass.
Approved April 18, 1899.

Type II (*a*), "recession." Water rises to carbide from below, so attacking the carbide that the rising water is greatly in excess at the point where carbide is decomposed.

Residuum withdrawn *wet* through valves.

Price of thirty-light plant, $125.00.

Claims of Manufacturers: fool-proof; self-acting, etc.

6. The "BENEDICT."

Manufactured by Union Light and Heat Co.,
232 W. Eighth St., Cincinnati, O.
Approved November 21, 1899.

Type I (*b*), "overflow."

No response to questions.

7. The "BERTIE L."

Manufactured by Shour Bros. Manufacturing Co.,
Chillicothe, Mo.
Approved November 21, 1899.

Type I (*b*), "overflow."

Residuum removed *wet* in buckets, same in which carbide is slaked.

About one hundred and ninety machines in use; none in Pennsylvania.

Cost of thirty-light plant, $65.00.

Claims of Manufacturers: simplicity of operation; cannot be tampered with while in operation, etc.

8. The "BRADDON."

Manufactured by Bishop, Rising & Braddon,
Quincy, Mich.
Approved November 21, 1899.

Type I (*b*), "overflow."
Repeated letters brought no response.

9. The "BRILLIANT."
Manufactured by Brilliant Acetylene Gas Machine Co.,
1717 Eighteenth St., Louisville, Ky.
Approved August 15, 1899.

Type I (*b*), "overflow." Has subdivided overflow carbide holder.
Residuum removed *wet* by taking out receptacle.
About twenty-five machines in use; none in Pennsylvania.
Cost of thirty-light plant, $140.00.
Claims of Manufacturers: best construction; perfect operation of parts, etc.

10. The "BUCHER."
Manufactured by Bucher Acetylene Gas Co ,
Alexandria, Pa.
Approved November 21, 1899.

Type I (*b*), "overflow."
Residuum removed *wet* in buckets, same in which carbide is contained.
About seventy-five twenty and thirty-light machines in use, and a few seventy-five lights; mostly in Pennsylvania.
Cost of thirty-light plant, $100.00.
Claims of Manufacturers: automatic; simple of construction; built of best material on the market; perfectly safe; never liable to get out of order; require very little attention; make all the gas the carbide contains, etc.

11. The "BUFFINGTON."
(This machine was approved by the Middle Department April 18, 1899. Its manufacture has been discontinued.)

12. The "CHACE."
Manufactured by the Chace Carbide and Gas Generator Co.,
Jamaica Plain, Mass.
Approved November 21, 1899.

Type I (*b*), "overflow."
Residuum removed *wet* in cans.
Has device for indicating that charge will be needed next day.
Cost of thirty-light plant, $175.00.
Claims of Manufacturers: simple and accurate in working; in all respects automatic; no valves to get out of order, etc.

13. The "CHICAGO."

Manufactured by Kennedy & Seavy,
Aurora, Ill.
Approved November 21, 1899.

Type I (*a*), "spray." (?)
No response to questions.

14. The "CHICAGO JEWEL."

Manufactured by Monarch Manufacturing Company,
208 S. Pennsylvania St., Indianapolis, Ind.
Approved November 21, 1899.

Type II (*b*), "dip."
Residuum removed *wet* by a pipe at the bottom of the generator.
About twenty-five machines in use; none in Pennsylvania.
Cost of thirty-light plant, $190.00.
Claims of Manufacturers: cool gas; complete generation, etc.

15. The "CLEVELAND."

Manufactured by Harris Manufacturing Co.,
47 Middle Street, Cleveland, O.
Approved September 19, 1899.

Type I (*b*), "overflow." (?) Makers say the type is a "combination, a proportionate amount of water just sufficient to liberate all the gas and keep it cool being admitted to a small quantity of carbide."

Residuum carried out *wet* in generator pans.

About forty machines in use; five in Pennsylvania.

Cost of thirty-light plant, $100.00.

Claims of Manufacturers: simplicity of construction and operation; economy; cool gas; no valves nor stop-cocks; manufactured from the best galvanized steel by experienced and expert workmen, etc.

16. The "CLINE."

Manufactured by Alexander Furnace and Manufacturing Co.
Lansing, Mich.
Approved November 21, 1899.

Type I (*b*), "overflow." (?)
No response to questions.

17. The "CORONA."

Manufactured by Corona Gas Light Co.,
Minneapolis, Minn.
Approved November 21, 1899.

No response to questions.

18. The "CRITERION," Model, "A."
Manufactured by J. B. Colt Co.,
404 E. Thirty-second St., New York, N. Y.
Approved February 21, 1899.

Type I (*b*), "overflow." Water is automatically fed to carbide, finally flooding it.

Residuum is removed *wet* by detaching the generating chambers and carrying them out for emptying.

Over two thousand in use; about one hundred in Pennsylvania.

Price of thirty-light plant, $100.00.

Claims of Manufacturers: only best quality material and workmanship used in construction; simplicity; absolutely automatic action; no valves; perfectly safe in hands of persons of average intelligence; cheapness to maintain, there being no waste from over-production; small cost, etc.

19. The "CRITERION," Model, "B."
Approved February 21, 1899.

20. The "CRITERION," Model "C."
Approved August 15, 1899.

NOTE.—These two machines by same manufacturers, were also exactly same in principle as Model "A," but being more expensive to manufacture, have been discontinued.

21. The "DAVIS."
Manufactured by Carbolite Construction Co.,
225 Dearborn St., Chicago, Ill.
Approved November 21, 1899.

Type III, "drop."

Residuum withdrawn *wet* through gate at bottom of machine.

Five machines in use; none in Pennsylvania.

Cost of thirty-light plant, $100.00.

Claims of Manufacturers: makes pure gas; residuum easily removed; provides for no loss by after-generation; applicable to large installations, etc.

22. The "DEMPSTER."
Manufactured by J. H. Dempster,
Des Moines, Iowa.
Approved November 21, 1899.

Type I (*b*), "overflow."

No response to questions.

23. The "DRAKE."

Manufactured by the International Heater Co.,

Utica, N. Y.

Approved September 19, 1899.

Type III, "drop." Measured quantities of carbide are dropped into large quantity of water.

Residuum removed *wet* through gate or valve.

Cans may be observed to tell whether they need recharging.

Cost of thirty-light plant, $150.00.

Claims of Manufacturers: maximum amount of gas per pound of carbide; no waste gas at any time; perfectly safe; no heat or pressure possible; ease of recharging; no clogging of burners, etc.

24. The "ELITE."

Manufactured by Elite Gas Generator Co.,

2116 Oregon Ave., St. Louis, Mo.

Approved November 21, 1899.

Type I (*b*), "overflow."

Residuum removed *wet* by taking out the carbide receptacle.

Cost of thirty-light plant, $100.00.

Claims of Manufacturers: superior workmanship throughout; strict compliance with the Underwriters' rules, etc.

25. The "EGER."

Manufactured by J. R. Eger,

Bay City, Mich.

Approved November 21, 1899.

Repeated letters elicit no response.

26. The "ERIE."

Manufactured by Keystone Acetylene Gas Co.,

Erie, Pa.

Approved November 21, 1899.

Type I (*b*), "overflow."

Repeated letters bring no response.

27. The "EXCELSIOR."

Manufactured by B. F. Bailey,

Lidgerwood, N. D.

Approved November 21, 1899.

Type I (*b*), "overflow."

Repeated letters elicit no response.

28. The "EXLEY."

Manufactured by Robert Exley,

612 Bannigan Building, Providence, R. I.

Approved November 21, 1899.

Type I (*b*), "overflow."
Residuum removed *wet* through valve at bottom.
Cost of thirty-light plant, \$100.00.
Claims of Manufacturers: all the gas from carbide, etc.

29. The "FAVORITE."
Manufactured by F. O. McQueen,
Scottsburg, Ind.
Approved November 21, 1899.

Type I (*b*), "overflow." Subdivided carbide pans.
Residuum removed *wet* in pans in which decomposition has taken place.
Eighty machines in use; none in Pennsylvania.
Cost of thirty-light plant, \$75.00.
Claims of Manufacturer: simplicity; strength of construction; satisfactory generation; accuracy, etc.

30. The "GAMMETER."
Manufactured by National Light and Heating Co.,
Freeport, Ohio.
Approved November 21, 1899.

Type I (*b*), "overflow."
No response to questions.

31. The "GOPHER."
Manufactured by C. M. Stroud & Co.,
Hastings, Minn.
Approved November 21, 1899.

Type I (*b*), "overflow."
No response to questions.

32. The "HOLMES."
Manufactured by Holmes-Bailey Acetylene Gas Co.,
Manton, Mich.
Approved November 21, 1899.

Type I (*b*), "overflow." Compartment flooding device.
Residuum removed *wet* in sectional bucket in which carbide is decomposed.
About seventy machines in use; none in Pennsylvania.
Cost of thirty-light plant, \$125.00.
Claims of Manufacturers: simplicity; positive assurance that machine will never fail to do its work, etc.

33. The "HOOSAC."
Manufactured by Wm. S. Nichols,
250 Broadway, New York, N. Y.
Approved August 15, 1899.

Type I (*b*), "overflow."
Residuum removed *wet* by lifting out holders and removing them for cleansing and recharging. Machine is constructed with two generators so that one can be recharged when the other is in use.
Claims of Manufacturer: double automatic generator; cool generation; full yield of gas, etc.

34. The "HUMAN."
Manufactured by the Human Gas Generator Co.,
Denver, Colo.
Approved November 21, 1899.
Repeated letters elicit no response.

35. The "INDIANA."
Manufactured by General Acetylene Supply Co.,
Kansas City, Mo.
Approved November 21, 1899.
No response to questions.

36. The "INTERNATIONAL SOLAR."
Manufactured by the United Acetylene Companies,
700 E. Main St., Richmond, Va.
Approved November 21, 1899.

Type I (*b*), "overflow."
Residuum removed *wet* by taking carbide pan from the generator.
Cost of thirty-light plant, $100.00.

37. The "KELSO."
Manufactured by Kelso Acetylene Gas Co.,
Vincennes, Ind.
Approved November 21, 1899.

Type I (*b*), "overflow." Divided compartment box.
Residuum removed *wet* by taking out carbide pan and dumping it.
About fifty machines in use; none in Pennsylvania.
Claims of Manufacturers: most perfect machine made, etc.

38. The "KENNEDY."
Manufactured by J. E. Kennedy,
Caledonia, Mich.
Approved November 21, 1899.

Type II (*b*), "dip."

Residuum removed *wet* by drawing off through a gate of sufficient size and capacity.

About one hundred and fifty machines in use; none in Pennsylvania.

List price of thirty-light plant, \$110.00.

Claims of Manufacturer: no danger; correct principle of generation; no waste; no odor; little attention; automatic action, etc.

39 The "KEYSTONE."
Manufactured by J. H. Dysart,
Johnstown, Pa.
Approved November 21, 1899.

Type I (*b*), "overflow." Subdivided pan.

Residuum removed *wet* in carbide pan.

Twenty machines in use; all in Pennsylvania.

Cost of thirty-light plant, \$80.00.

Claims of Manufacturer: simplicity; safety, etc.

40. The "KOHINOOR."
Manufactured by Western Acetylene Gas Co.,
Chicago, Ill.
Approved November 21, 1899.

Repeated letters elicit no response.

41. The "KOPF."
Manufactured by The M. B. Wheeler Electric Co.,
Grand Rapids, Mich.
Approved April 18, 1899.

Type I (*b*), "overflow." Has double generator.

No response to questions.

42. The "LAUN" or "SIMPLEX."
Manufactured by Laun Brothers,
763 W. Sixty-third St., Chicago, Ill.
Approved June 20, 1899.

Type I (*b*), "overflow."

Residuum removed *wet* by carrying out pan.

Claims of Manufacturer: cool generation; no waste of gas; simplicity; durability, etc.

43. The "LOWENSTINE."
Manufactured by J. Lowenstine,
Valparaiso, Ind.
Approved November 21, 1899.

Type I (*b*), "overflow."

Residuum removed *wet* in carbide pans.

Eight machines in use; none in Pennsylvania.

Cost of thirty-light plant, $135.00.

Claims of Manufacturer: no danger, even if mistakes are made; air mixture reduced to minimum; simplicity; water feed entirely controlled by gas consumed, etc.

44. The "McGRANE."

Manufactured by The McGrane Acetylene Gas Co.,
187 Broadway, New York, N. Y.
Approved June 20, 1899.

Type I (*b*), "overflow."

The McGrane people write under recent date: "The acetylene generator business has practically passed out of our hands."

45. "The "MARTINDALE."

Manufactured by the Kinnear Manufacturing Co.,
Warren, Pa.

Type III, "drop." Charges of carbide in buckets are dropped as needed by a simple mechanical device.

Residuum withdrawn *wet* by means of a round way cock, and in part by removing the buckets.

A simple but sure mechanical indicator shows at all times the number of unused buckets of carbide.

Thirty-light size not made; cost of thirty-five-light plant, $125.00.

Claims of Manufacturers: cool and pure gas; no carbonizing; producing all the gas from carbide; simple; compact; complete machine, requiring no mechanic to set it up, after leaving the factory, etc.

46. The "MEDBERY."

Manufactured by The Acetylene Apparatus Company.
204 Industrial Trust Co. Building, Providence, R. I.
Approved April 18, 1899.

Type I (*b*), "overflow."

Residuum removed *wet* in special receptacles.

About twenty machines in use; none in Pennsylvania.

Thirty-light size not made; cost of twenty-five-light plant, $100.00. f. o. b. Greenwich, R. I.

Claims of Manufacturers: small after- generation; no blowing-off; no escape of gas; easy charging, etc.

47. The "MONARCH."
Manufactured by The Monarch Acetylene Gas Co.,
1022 Douglas St., Omaha, Neb.
Approved November 21, 1899.

Type I (*b*), "overflow." Water rises to carbide.
Residuum removed *wet* by taking out carbide receptacle.
About one hundred machines in use; none in Pennsylvania.
Cost of thirty-light plant, retail, $100.00.
Claims of Manufacturers: right principle; cool generation; pure gas; convenient management; unsurpassed construction and finish, etc.

48. The "MORLEY."
Manufactured by Jas. H. Morley,
Springfield, Mass.
Approved November 21, 1899.
Repeated letters elicit no response.

49. The "NATIONAL OF CLEVELAND."
Manufactured by The National Acetylene Gas Co.,
909 New England Building, Cleveland, O.
Approved April 18, 1899.

Type I (*a*), "spray."
Residuum removed *dry* by lifting out holder.
Cost of thirty-light plant, $150.00.
No response to questions.

50. The "NEW DEPARTURE."
Manufactured by The Departure Gas Co.,
Centerburg, O.
Approved November 21, 1899.

Type III, "drop."
Has mechanical device to show amount of carbide consumed.
Residuum removed *wet* in buckets, which receive same while machine is working and are brought to surface by a lever.
Cost of thirty-two-light plant, $135.00, at present cost of material.
Claims of Manufacturers: convenience in charging; pure, cool gas; correct principle; simplicity; durability; safety, etc.

51. The "NEW GEM."
Manufactured by T. J. Hamblen,
New Sharon, Iowa.
Approved November 21, 1899.

Type I (*b*), "overflow."

Residuum removed *wet* in carbide receptacle.

Twenty-eight machines in use; none in Pennsylvania.

Cost of thirty-light plant, $110.00.

Claims of Manufacturer: simple construction; reliable automatic operation; durable; economical, etc.

52. The "NEW ULM."
Manufactured by W. F. Laudenschlager,
New Ulm, Minn.
Approved November 21, 1899.

Repeated letters elicit no response.

53. The "NIAGARA FALLS."
Manufactured by Niagara Falls Acetylene Gas Machine Co.,
Niagara Falls, N. Y.
Approved February 21, 1899.

Type I (*a*), "spray." One or more carbide boxes, according to size. A larger number may receive water in rotation.

Residuum removed *dry* by an especially designed contrivance which prevents dust from coming into the air or dropping on the floor. A shaker enables the operator to ascertain about the quantity of unused carbide in the machine, the carbide resting on a grate like a stove grate.

About two thousand machines in use; forty in Pennsylvania.

Cost of thirty-light plant, $90.00.

Claims of Manufacturers: superior workmanship; first class material; no valves, cocks, or flexible joints; simple to care for, etc.

54. The "NORFOLK."
Manufactured by The Norfolk Acetylene Co.,
Norfolk, Neb.
Approved November 21, 1899.

Type I (*b*), "overflow."

Repeated letters elicit no response.

55. The "NORTHLIGHT."
Manufactured by The Pan-American Acetylene Co.,
Buffalo, N. Y.
Approved April 26, 1899.

Type II (*a*), "recession."

Residuum removed *wet* by opening a large molasses gate.

A rod indicates height of unconsumed carbide in generator.

Two hundred and ninety machines in use; fifty in Pennsylvania.

Cost of thirty-light plant, $130.00.

Claims of Manufacturers: cool generation; all gas from carbide, etc.

56. The "NO VALVE."
Manufactured by T. H. J. Leckband,
Adair, Iowa.
Approved June 20, 1899.

Type I (*b*), "overflow." Compartments contain about two pounds each in any size of generator.

Residuum taken away *wet* by removing a draw.

Cost of thirty-light plant, $50.00, f. o. b. Adair, Iowa, wholesale.

57. The "ODORLESS."
Manufactured by J. A. Brown,
Faribault, Minn.
Approved November 21, 1899.

Type I (*b*), "overflow." Divided carbide pans.

Residuum removed *wet* by withdrawing pans.

Cost of thirty-light plant, $135.00.

Claims of Manufacturer: simplicity, etc.

58. The "O'HERRON."
Manufactured by Dougherty & O'Herron,
Princeton, Ind.
Approved November 21, 1899.

Repeated letters elicit no response.

59. The "PEERLESS."
Manufactured by Ezra Farnsworth,
Minneapolis, Minn.
Approved April 18, 1899.

Type II (*b*), "dip." A rising bell lifts bucket of carbide out of water.

Residuum removed *wet* by lifting carbide pail out of gas-holder. Can be removed dry if preferred.

Claims of Manufacturer: no complex parts to get out of order; efficient, reliable, etc.

60. The "POSITIVE."
Manufactured by Hancock Gas Generator Co.,
Hancock, N. Y.
Approved June 20, 1899.

Type III, "drop."

Residuum drawn off *wet* at bottom.

Mechanical indicator shows when recharging is necessary.

About twenty machines in use; ten in Pennsylvania.

Cost of thirty-light plant, $150.00, retail.

Claims of Manufacturers: generates cool gas; does not clog burners, etc.

61. The "PREMIER."

Manufactured by The Premier Acetylene Gas Co.,
403 Oak St., Chicago, Ill.
Approved November 21, 1899.

Type II (*a*), "recession."

Residuum removed *wet* by carrying buckets out, a special container being furnished for the purpose.

Thirty-seven machines in use; none in Pennsylvania.

List price of thirty-light plant, $140.00.

Claims of Manufacturers: simplicity; safety; economy; no petcocks; excellent construction, etc.

62. The "RAND."

Manufactured by E. A. Rand & Son,
North Adams, Mass.
Approved June 20, 1899.

Type I (*b*), "overflow." Separate generators.

Residuum removed *wet* by detaching generator.

Eight machines in use; none in Pennsylvania.

Cost of thirty-light plant, $135.00.

Claims of Manufacturers: simplicity; economy; durability; uniform pressure; little attention, etc.

63. The "READ-HOLLIDAY."

Manufactured by Read Holliday Acetylene Co., Lim.,
100 William St., New York, N. Y.
Approved April 18, 1899.

Type II (*a*), "recession." An English machine with many customers in England.

No response to questions.

64. "The "REX."

Manufactured by The Rex Acetylene Generator Company,
Norwich, N. Y.
Approved August 15, 1899.

Type I (*b*), "overflow." Compartment holder; double generator.

Residuum removed *wet* by withdrawing holder.

Ninety-five machines in use; twenty-one in Pennsylvania.

Cost of thirty-light plant, $110.00.

Claims of Manufacturers: perfect mechanical construction; no gas liberated on recharging; no concealed working parts; cool generation, etc.

65. The "ROSS."
Manufactured by The Ross Generator Co.,
Lafayette, Ind.
Approved November 21, 1899.

Type I (*b*), "overflow." Compartment, or cell plan.

Residuum removed *wet* by scraper provided in each compartment.

Cost of thirty-light plant, $90.00.

Claims of Manufacturers: safety; economy; good regulation; cool generation; convenience; little attention, etc.

66. The "SECURITY."
Manufactured by Holt Brothers & Rose,
Syracuse, Neb.
Approved November 21, 1899.

Type II (*a*), "recession."

No response to questions.

67. The "SIMPLEX."
Manufactured by Eastern Solar Gas Machine Co.,
120 Liberty St., New York, N. Y.
Approved June 20, 1899.

Type I (*b*), "overflow."

This is substantially the same machine as the "Laun" or "Simplex," No. 14, above.

No response to questions.

68. The "SOBER AND PORTER."
Manufactured by C. K. Sober & Porter,
Lewisburg, Pa.
Approved October, 1899.

Type I (*b*), "overflow." Water flows to carbide in successive retorts, flooding them completely.

Residuum removed *wet* in the detachable retorts.

Thirteen machines in use; all in Pennsylvania.

Cost of thirty-light plant, $135.00.

Claims of Manufacturers: easy to charge; no danger from admission of air; gas always uniform, etc.

69. The "SPERRY."
Manufactured by S. L. Sperry,
Hebron, Neb.
Approved November 21, 1899.

No response to questions.

70. The "STANDARD."
Manufactured by M. E. Peters,
Denver, Colo.
Approved November 21, 1899.

Type III, "drop."

Repeated letters elicit no response.

71. The "STREET."
Manufactured by Street Acetylene Gas Machine Co.,
Wichita, Kansas.
Approved November 21, 1899.

Type I (*b*), "overflow."

No response to questions.

72. The "SUNLIGHT BY NIGHT."
Manufactured by John Condon,
804 Callowhill St., Philadelphia, Pa.
Approved November 21, 1899.

Type III, "drop."

Residuum removed *wet* by gravity.

Glass indicator in carbide holder shows when generator requires recharging.

Fifteen machines in use; all in Pennsylvania.

Cost of twenty-five-light plant, $160.00.

Claims of Manufacturer: cool, pure gas; little attention; greater carbide capacity; all gas secured from carbide, etc.

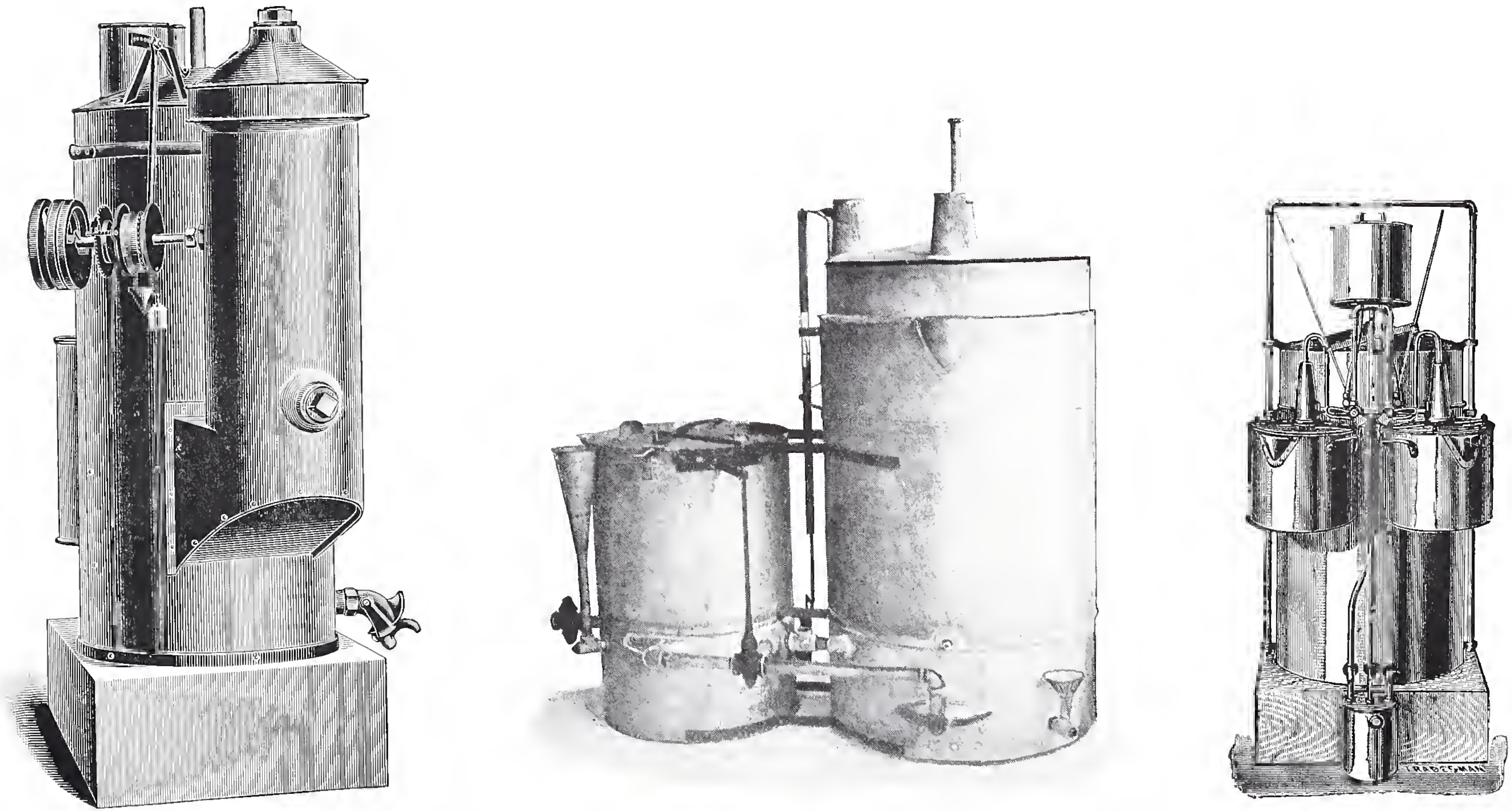
73. The "SUPERIOR."
Manufactured by Superior Gas Generator Co.,
Minneapolis, Minn.
Approved November 21, 1899.

Type II (*b*), "dip."

No response to questions.

74. The "TANNER."
Manufactured by Drake Acetylene Apparatus Co.,
Cleveland, O.
Approved November 21, 1899.

The manufacture of this machine is discontinued.



A GROUP OF ACETYLENE GENERATORS. THREE DIFFERENT MAKES.

75. The "TRIUMPH."
Manufactured by Craig-Reynolds Foundry Co.,
Dayton, O.
Approved April 18, 1899.

Type I (*a*), "spray."
No response to questions.

76. The "TROUBETZKOY."
Manufactured by The Mechanical Engineering Construction Co.,
63 Fifth Ave., New York, N. Y.
Approved August 15, 1899.

Type I (*a*), "overflow." Water comes to separate boxes of carbide, within one generator, flooding each in succession; one generator exhausted, water flows to another, and so on.

Residuum removed *wet* in the boxes, adequate pipes removing the water.

One hundred and ninety-two machines, aggregating seventeen thousand eight hundred and ninety lights, in use; eight in Pennsylvania, aggregating fifteen hundred and twenty lights. These manufacturers make a specialty of large installations.

Cost of thirty-light plant, $715.00.

Claims of Manufacturers: absolute control of generation, which is always in proportion to consumption; pure gas; unlimited capacity of machine; no rubber or leather packing; no stuffing boxes; only one working part on each apparatus, etc.

77. The "U. S. STANDARD."
Manufactured by The Denver Acetylene Co.,
Denver, Colo.
Approved November 21, 1899.

Type III, "drop."

Residuum removed *wet* in special receptacles.

Twenty-five machines in use; none in Pennsylvania.

Cost of twenty-five-light plant, $100.00.

Claims of Manufacturers: no admixture of air; no escape of gas while recharging or otherwise; no need to open any pipe where gas is generated or stored; cool generation; pure gas, etc.

78. The "VENUS."
Manufactured by E. C. Hoffman,
Plainfield, Ill.
Approved November 21, 1899.

Type I (*b*), "overflow." Divided pan generator.

Residuum removed *wet* by removing cell pan and emptying.

Twenty-two machines in use; none in Pennsylvania.

Cost of thirty-light plant, $100.00.

Claims of Manufacturer: cool generation; perfect automatic action; no waste, etc.

79. The "X."

Manufactured by The New England Acetylene Gas Machine Co.

Springfield, Mass.

Approved November 21, 1899.

Repeated letters elicit no response.

GENERATORS APPROVED BY UNDERWRITERS OTHER THAN THE MIDDLE DEPARTMENT.

The following generators, approved, but not by the Middle Department, are briefly mentioned. The approval is in all cases either by the South Eastern Tariff Association, of Atlanta, or by the Underwriters' Bureau of Fire Protection Engineering, of Chicago. The former Board is indicated by the letters "S. E.," the latter by "W." In the latter, the approvals for the most part were previous to the promulgation of the National Board rules.

80. The "AMERICAN." (About forty in use.)

American Acetylene Gas Machine Co.,

Minneapolis, Minn.

Type II (*b*), "dip." App. by W.

81. The "APOLLO."

Electro Gas Lighting Co.,

Baltimore, Md.

Type ? App. by S. E.

82. The "AUTOMATIC MAGAZINE." (About forty in use; five in Pennsylvania.)

Bryan Manufacturing Co.,

Baltimore, Md.

Type III, "drop." App. by S. E.

83. The "AUTOMATIC SINGLE CHARGE." (About fifty in use; four in Pennsylvania.)
Bryan Manufacturing Co.,
Baltimore, Md.
Type II (*b*), "dip." App. by S. E.

84. The "BRUCE." (About three hundred in use.)
Karst & Breher,
St. Paul, Minn.
Type I (*a*), "spray." App. by W.

85. The "BUCKEYE."
The Price Manufacturing Co.,
Freeport, O.
Type I (*b*), "overflow." App. by W.

86. The "CASTANA." (About one hundred in use.)
Castana Acetylene Gas Co.,
Castana, Iowa.
Type I (*b*), "overflow. App. by W.

87. The "CLIMAX." (One hundred and eighty-seven in use.)
New Process Manufacturing Co.,
Dallas, Tex.
Type III, "drop." App. by S. E.

88. The "CROWN."
Detroit Galvanizing and Sheet Metal Works,
Detroit, Mich.
Type I (*a*), "spray." App. by W.

89. The 'DAYLIGHT."
Daylight Acetylene Gas Co.,
Louisville, Ky.
Type I (*a*), "spray." App. by W.

90. The "DRAPER."
Draper Manufacturing and Gas Co.,
Dana, Ind.
Type I (*b*), "overflow." App. by W.

91. The "DUPLEX."
Electro Gas Lighting Co.,
Baltimore, Md.
[illegible] App. by S. E.

92. The "EMANSEE." (Several hundred in use.)
McGovern Manufacturing Co.,
Chicago, Ill.
Type I (*a*), "spray." App. by W.

93. The "EUREKA." (Four hundred and eighty-two in use.)
F. W. Arney & Co.,
Terre Haute, Ind.
Type I (*a*), "spray." App. by W.

94. The "FIERCE DAYLIGHT." (Forty-seven in use.)
J. C. Charbeneau,
Mount Clemens, Mich.
Type I (*a*), "spray." App. by W.

95. The "HARGER." (Sixty-eight in use.)
Jenks & Son,
Prairie City, Iowa.
Type I (*a*), "spray." App. by W.

96. The "IDEAL EPWORTH." (Five hundred in use.)
Epworth Gas Light and Heating Co.,
Waterloo, Iowa.
Type I (*a*), "spray." App. by W.

97. The "LECKBAND."
Leckband Acetylene Co.,
Adair, Iowa.
Type I (*b*), "overflow." App. by W.

98. The ""LEEDE." (One hundred and ten in use.)
Solar Acetylene Gas Co.,
Minneapolis, Minn.
Type III, "drop." App. by W.

99. The "LONE STAR." (Fifty in use.)
Lone Star Acetylene Gas Co.,
Tyler, Tex.
Type I (*a*), "spray." App. by S. E.

100. The "MARQUETTE."
The Marquette Manufacturing Co.,
St. Louis, Mo.
Type I (*a*), "spray." App. by W.

101. The "MILLER'S IMPROVED." (Ten machines in use.)
Wm. Miller,
Thomasville, Ga.
Type III, "drop." App. by S. E.

102. The "NATIONAL SUNLIGHT." (About two thousand machines in use.)
National Sunlight Gas Co.,
Davenport, Iowa.
Type I (*b*), "overflow." App. by W.

103. The "NEW ERA." (About twenty in use.)
Bryan Manufacturing Co.,
Baltimore, Md.
Type, see note. App. by S. E.

NOTE.—The above generator is so different from the ordinary type as to call for special mention. The machine is designed to avoid the necessity of protection from freezing and to this end omits the use of the bell gas-holder altogether. Gas is generated by carbide in a basket coming in contact with water, but so regulated that the first pressure secured very delicately lifts the basket from the water again. The gas passes through a check valve to a receiver from which it advances through a reducing pressure valve to the pipes. The pressure in the generator can never exceed a fixed amount, say two or three pounds, capable of careful regulation by a safety valve. The contact of the broad bottomed carbide basket with water is especially delicate and the machine is worthy of attention, if for no other reason, because of its departure from the usual style. The generator is very compact and simple.

104. The "ONTARIO." (Twelve machines in use; two in Pennsylvania.)
Ontario Acetylene Gas Machine Co.,
West Palm Beach, Fla.
App. by S. E.

105. The "ORDWAY."
National Acetylene Gas Generator Co.,
Corning, N. Y.
Type III, "drop." App. by W.

106. The "OWEN." (Four hundred machines in use.)
Geo. F. Owen,
Grand Rapids, Mich.
Type I (*a*), "spray." App. by W.

107. The "PATTERSON." (About one hundred and fifty machines in use.)
Patterson Generator Co.,
Batavia, N. Y.
Type I (*a*), "spray." App. by W.

108. The "SHAKOPEE."
Shakopee Generator Co.,
Shakopee, Minn.
Type II (*b*), "dip." App. by W.

109. The "SIMPLEX." (of La.)
W. H. Moody Manufacturing Concern,
Shreveport, La.
Type I (*b*), "overflow." App. by S. E.

110. The "SOLAR."

Eastern Solar Gas Machine Co.,
New York, N. Y.
Type I (*b*), "overflow." App. by W.

111. The "SUBMARINE." (Thirty-nine machines in use.)
Sunlight Gas Machine Co.,
Augusta, Ga.
Type III, "drop." App. by S. E.

112. The "SUN." (Two hundred and eighteen machines in use.)
Frank W. Preussel,
Mount Clemens, Mich.
Type I (*a*), "spray." App. by W.

113. The "SUNLIGHT AUTOMATIC." (About twenty-five machines in use.)
Acetylene Gas Machine Co.,
Bridgewater, Va.
Type I (*a*), "spray." App. by S. E.

114. The "TAYLOR."
Taylor Acetylene Gas Co.,
New York, N. Y.
Type I (*a*), "spray." App. by W.

115. The "TURNER."
Turner & Hauser,
Grand Rapids, Mich.
Type I (*a*), "spray." App. by W.

116. The "UNIQUE."
Sunlight Gas Machine Co.,
Augusta, Ga.
Type I (*a*), "spray." App. by S. E.

117. The "VICTOR."
Victor Manufacturing Co.,
New London, O.
Type I (*b*), "overflow." App. by W.

118. The "VINKLE AUTOMATIC VALVELESS."
Lucas Brothers,
Minneapolis, Minn.
Type I (*a*), "spray." App. by W.

119. The "YANCEY."
Yancey & Dussel,
New Orleans, La.
Type II (*b*), "dip." App. by S. E.

PENNSYLVANIA MACHINES.

Those of the above mentioned machines which are made within our State, all of them properly approved generators, are here mentioned together for convenience. For details reference is made to their descriptions under the respective numbers above. They are:

10. The "BUCHER." Manufactured at Alexandria.
39. The "KEYSTONE." Manufactured at Johnstown.
45. The "MARTINDALE." Manufactured at Warren.
68. The "SOBER AND PORTER." Manufactured at Lewisburg.
72. The "SUNLIGHT BY NIGHT." Manufactured at Philadelphia.

UNAPPROVED MACHINES.

While the writer has unhesitatingly advised the use of insurance approved machines, and thinks no other advice equally safe, he does not mean to imply that unapproved machines are all disapproved. This does not follow at all. There are some generators which comply with all the requirements of the Underwriters, but which for reasons best known to the manufacturers, have not been submitted for inspection. But there are others which have been rejected, and as this report may fall largely into the hands of those who may not have the facilities of accurately judging as to the qualities of a machine, the writer can find no other safe ground of advice.

To attempt a list and description of unapproved machines would surely work injustice to some, as it would be impossible to prepare anything like a complete one, hence no such generators are mentioned.

COST OF ACETYLENE ILLUMINATION.

The cost of acetylene illumination is necessarily made up of two elements: (1) the first cost of the machine and its installation, and (2) the current expense for carbide, etc.

As shown in the above lists of generators, the cost, based on a thirty-light installation, varies from eighty to one hundred and seventy-five dollars or more, as stated by the manufacturers, but it is entirely impracticable to make a correct allowance for discounts, fluctuations, etc. While a thirty-light machine is larger than many would require, yet it is advisable to purchase abundantly large for present needs. There may be occasion to increase the number of lights later on, to light the stables and out-houses, or to use the gas for cooking. Lower prices for carbide will also develop new uses for acetylene. But it is most important to select a generator which is thoroughly well made, and it is not economy to select the lowest priced machine and tolerate cheap construction. Neither is it economy to be attracted by the low price of an apparatus which has been "marked down" to compete with a better selling machine which brings a higher price because it is constructed on a wiser plan. For the ordinary house of moderate dimensions, something over one hundred dollars must be allowed for the machine itself. If the house is piped for gas, the old piping and fixtures will do equally well if not better; the burners alone will need to be changed. If new piping is required, only about half the size requisite for city gas is usually employed for acetylene, and the cost of this is a matter of local conditions. Nor need the matter of placing a pipe system even in a completed and finely finished residence be regarded as objectionable. With a little care it can be thoroughly concealed beneath the floors and within the walls. On this topic, "The Acetylene Gas Journal," of Buffalo, N. Y., printed a very readable and sensible article in its issue of June, 1899, and any one who contemplates piping a finished house for acetylene gas would do well to secure that article.

The present cost of carbide may be stated at eighty dollars per ton, or in small quantities four and a half cents per pound. Since a pound of carbide yields, as a conservative estimate, four and a half cubic feet of gas, a safe and reasonably close approximation is made when the cost of acetylene is stated at one cent per cubic foot, aside from the first cost of the installation. And when it is considered that the commonest acetylene burner in use (one-half foot) consumes only one-tenth as much gas per hour as the usual coal gas burner (five foot), acetylene is found competing with coal gas at one dollar per thousand, a lower price for the latter commodity than is often realized. And when the greater illuminating power of acetylene gas is considered, it may be stated with little likelihood of challenge that,

light for light, acetylene is cheaper than coal gas. The writer has seen a large number of letters from householders, storekeepers and others using acetylene gas, who declare without reserve that their present light is not only vastly better, but also much cheaper than their former coal oil illumination. Further as the acetylene flame is always burned free, without shade or chimney, there may be at once eliminated from all estimates any allowance for expense of broken globes, chimneys, shades or incandescent mantles, an item of no inconsiderable importance which is often underestimated in making calculations of prospective expense. Another matter of importance is that all the light produced is utilized without diminution of its intensity by opaque globes, shades or chimneys, for it is to be remembered that even clear glass absorbs a perceptible percentage of light which is never utilized by those who derive their artificial light from flames surrounded by glass or porcelain.

The following also seems to be a fair statement of the comparative cost of the two illuminants, based on twenty candle power light:

Acetylene gas, at \$0.05 per pound, for carbide, costs 0.5 cents per hour.

Acetylene gas, at \$0.045 per pound, for carbide, costs 0.45 cents per hour.

Acetylene gas, at \$0.04 per pound, for carbide, costs 0.4 cents per hour.

Ordinary gas, at \$1.00 per thousand, costs 0.5 cents per hour.

Ordinary gas, at \$1.25 per thousand, costs 0.625 cents per hour.

Ordinary gas, at \$1.50 per thousand, costs 0.75 cents per hour.

It is true that many an acetylene trade catalogue presents figures so much more favorable to aceylene than the above that, if credence were accorded them, one could but wonder why acetylene does not at once expel coal gas and electricity from use. The sophistry and bombast of such irresponsible people is to be carefully avoided, lest one be led astray. On the other hand, the devotees of coal gas, the journals which represent the capital invested in that industry, may very likely display calculations at times which would indicate that acetylene must promptly and irrevocably fail. As between the two, the strides with which acetylene has bounded into popularity must serve to direct our judgment, and while the contention can hardly be that acetylene is fitted by its nature and its present cost, to compete with coal gas in the cities and towns, the statements given above may be reasonably relied upon as showing the fitness of the new gas for inexpensive and beautiful lighting of isolated factories, of churches, stores, small country villages, and particularly of rural homes. And the figures given in this chapter on the expense of acetylene illumination may be treated as reasonably reliable, showing the results of

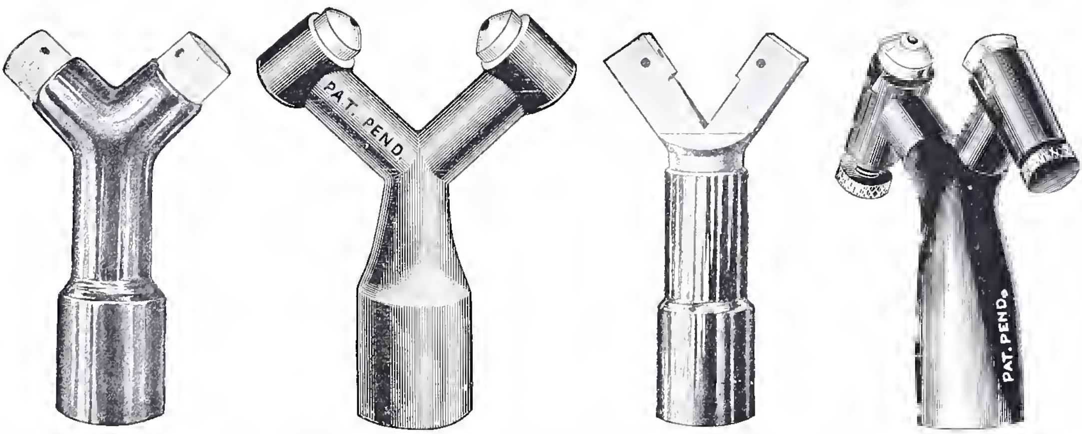
the best experience at the present time, assuming always a well made, safe, reliable generator of responsible manufacture.

It is believed by those who are in a position to speak with some authority, that there is likely to be a considerable fall in the price of carbide within a year or two; and it is not even occasionally predicted that the price will increase. So, while it is not the writer's province to prophesy, it may yet be assumed as more probable than otherwise that acetylene will become distinctly cheaper.

BURNERS.

It is not practicable to utilize acetylene in the usual burners employed for other gas. The burners must pass less gas and be especially constructed to meet the demands made upon them. Much ingenuity has been expended in producing good acetylene burners, with the result that there are on the market to-day a large number of different types which serve their purpose admirably.

The first and most serious difficulty was in finding a burner in

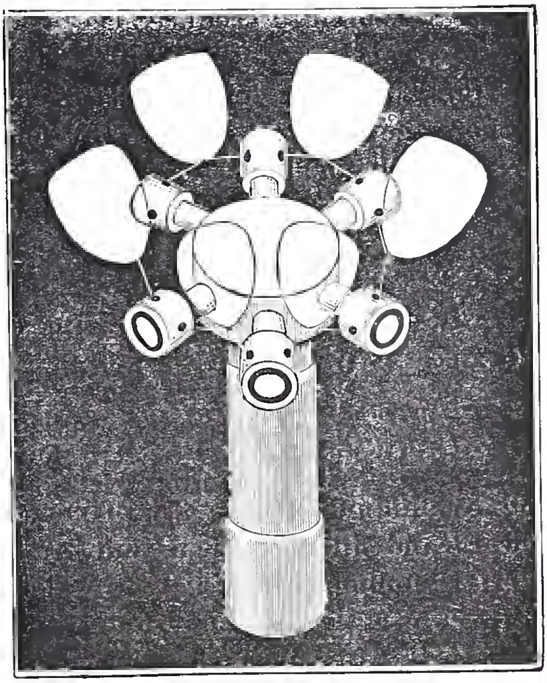


A GROUP OF ACETYLENE BURNERS. DIFFERENT MAKES.

which acetylene could be consumed without the nuisance of smoking and clogging. This was because the burner of ordinary form becomes too hot, the gas polymerizes as was explained under the properties of acetylene, and the condensation products penetrate the material of the burner and, charring, clog the passages with soot. The problem of finding a burner which should not exhibit this objectionable character has been solved by the introduction of burners in which two small jets of acetylene are discharged from two different points in the burner, so directed that they impinge upon each other at a slight distance from the burner forming a flat flame which stands at a right angle to the plane in which the jets lie. These jets also carry air with them, taken in at the burner by the aid of a device which is similar in principle to a Bunsen burner on a small scale. The injected air is merely sufficient to bring about a complete and

smokeless combustion, and the flame itself is so remote from the burner that the latter scarcely becomes heated.

In the earlier forms of branched burners, when metal was employed, it was found that even the slight heating to which they are subjected would, in time, warp the tube so that they would cease after a while to work "true," and would begin to smoke when used but a few hundred hours. This has been obviated by a modified construction of the metal burner or by substituting steatite for the metal in the branching portion, and thus, in different ways, burners are now available which do not either smoke or clog after many hundred hours of use. It may be remarked here that the quality of the gas has much to do with the excellent operation of the burner. A gas which has been overheated in the generator in disregard of all precautions



A SIX FLAME ACETYLENE BURNER.

concerning cool generation, a matter under the absolute control of any one selecting a generator, will most surely carry with it products other than pure acetylene, which will cause it to behave badly even in the most approved and perfect burners.

Again, it is false economy to "turn down" the ordinary acetylene burner, as this causes the air injection to refuse to work, brings the flame nearer the burner, heating the latter and thus defeating the very object of its careful construction and causing it to become clogged and smoky, which once accomplished is difficult if not impossible to remedy. The burner shown at the extreme right of the group above is possibly an exception to this. This cut exhibits an "adjustible" burner, which may be turned down from a full sized

flame to one candle power by means of the thumb screws which attach to needle valves controlling the gas flow. It is stated that the valves will effectually clear the jets if they should become stopped, and further that one jet may be closed entirely and the other reduced to as small a flame as desired for a night light, without smoking. The flame of all acetylene burners is small, but there is no dark, non-illuminating portion common with other gas. We are likely to underestimate its lighting power because of its small size, but this is more than offset by its great intensity. All good burners produce a delightfully steady, quiet and agreeable flame, free from flickering.

FREEZING.

As water is necessarily used to produce acetylene, and as it is also usually employed for seals, as well as for washing the gas and for the operation of the holder, it follows that acetylene generators must be placed where they can not freeze. On the other hand, there should be no fire near such a machine. The proper arrangement is to install a generator in a protected space where the temperature never falls below freezing, or supply the generator room with a small radiator or coil fed with hot water or steam. Whatever may be the method of securing the result, it is absolutely necessary that a generator must be located that it can not freeze.

DISPOSITION OF RESIDUUM.

The liquid and semi-liquid refuse may of course be passed into the ordinary sewers and allowed to accompany the sewage upon which it can exert no influence other than that of a partial disinfectant. But there is usually a solid residue which must be otherwise disposed of. If dry, it may have some odor which persists so long as there is any decomposed carbide in it, which gradually finding moisture, can yield acetylene. But this is wasteful and most machines now give up their refuse in a flooded state. Wet residuum has little odor and may be thrown with the ashes from the heater, or otherwise dumped in the most convenient place. Many recommend its use as a fertilizer; in this connection it may not be out of place to submit the analysis of carbide residuum. The following figures show the analysis of two specimens of refuse taken at remote times and places. They are as follows:

	I.	II.
Sand, per cent.,	1.10	0.97
Carbon, per cent.,	3.95	2.14
Oxide of iron and alumina, per cent.,	2.90	2.30
Lime, per cent.,	63.65	66.10
Water and carbonic acid, per cent.,	28.40	28.49
Total,	100.00	100.00

I. is an analysis by Professor E. H. Jenkins, of New Haven, Conn., of refuse from a Troubetzkoy machine. II. is an analysis made under the writer's direction at the Pennsylvania State College, of refuse from a Northlight machine. In order to present an authoritative statement of the fitness of these residues for application to the soil, the above analyses were submitted to Dr. H. P. Armsby, Director of the Agricultural Experiment Station of The Pennsylvania State College, with a request for a statement, regarding the use of such residues for agricultural purposes. The following response was received:

State College, Pa., Dec. 30, 1899.

Professor G. G. Pond, State College, Pa.:

Dear Sir: The two analyses submitted by you of the residuum drawn from acetylene machines show it to consist essentially of a mixture of hydrate and carbonate of lime. It has substantially the same composition as the form of lime ordinarily applied in agriculture and I can see no reason why it is not a good form of lime for this purpose. Upon the basis of the analyses submitted, one ton of the residuum would be equivalent to one hundred and sixty bushels of lime of the best quality.

Very respectfully yours,

(Signed.) H. P. ARMSBY,
Director.

Aside from the use of acetylene refuse as a fertilizer, various propositions have been entertained to a greater or less extent. It has been used as a mortar, as a disinfectant for closets, as white-wash, as a light non-conductor of heat, and for paving purposes.

PURIFICATION.

The question of the purification of acetylene is being vigorously agitated at the present time, especially in Germany. No issue of either of the German acetylene periodicals, this season, is free from discussions bearing on this point. Some excellent suggestions have

been made but no final conclusions have been reached. The question, as has been shown, is not a vital one. The removal of the last traces of accompanying impurities in commercial acetylene is by no means a necessity, though it may be a thing to be desired. Most of the many thousands of homes lighted by acetylene in this country to-day, employ no method of purification other than the water washing to which the gas is submitted in every good generator, yet no harm whatever results from this omission. Nearly all of the American manufacturers believe that chemical purification is not practicable and is uncalled for. The time is not yet at hand for advising how the gas shall best be freed a little more perfectly, if possible, from the last traces of accompanying impurity. That time will come, but when it does, the purifying apparatus can be attached to any machine or inserted between the machine and the pipes with little trouble and at trifling cost.

In the meantime users of acetylene need have no uneasiness about the matter. Whenever an inexpensive but reliable chemical purifier can be honestly recommended to the trade, and such apparatus comes into general use, the principle effect of its introduction will be to accomplish an improved combustion, with less liability to carbonizing, but the improved conditions from a sanitary point of view will be imperceptible. That a perfect acetylene generator ought to have a purifier is not to be disputed, but this is only saying that nothing is so good as to be beyond the reach of possible improvement.

CARBOLITE.

As this term is occasionally seen in connection with acetylene, it may be well to give it a word of explanation. In preparing this product, it is proposed to impregnate blast furnace slag direct from the furnaces with pulverized coke, and to subject this mixture at once to the heat of the electric furnace, whereby the bases of the slag, forty to forty-five per cent. lime, with some alumina, magnesia, etc., will be converted into carbides. Such a process would yield a result which would contain forty-five to fifty per cent. of carbide of calcium, indefinite small quantities of other carbides, and a large amount of inert material. With water it yields an acetylene mingled with other gases and produces an abundance of refuse probably twice as great as is left by ordinary carbide. The cheapness of the process is probably more than counterbalanced by the undesirability of the product, and the writer cannot predict any large and brilliant future for carbolite.

LARGE PLANTS.

The usefulness of acetylene is not necessarily limited to small installations adapted to single small buildings. Larger establish-

ments such as factories, groups of summer hotels, schools or colleges, public institutions, etc., particularly when somewhat isolated in location so as to be beyond the reach of city gas supplies, may often be very beautifully and economically illuminated with acetylene gas. A conspicuous pioneer in this direction was the Niagara University, at Niagara Falls, N. Y. This institution was one of the earliest in this country to make use of acetylene illumination, and its first plant installed some four years ago when acetylene was entirely new has recently been replaced by a battery of quite modern machines. The clergy of the University received the writer with the utmost cordiality on the occasion of his recent visit there and expressed to him their entire satisfaction with their illumination as regards its efficiency and economy as well as with the little care needed and the great convenience of their plant. A more recent installation may be found at the Ohio State Girls' Industrial Home, at Rathbun, Ohio, where the eleven large buildings of that institution are lighted by five hundred jets of acetylene gas generated at a central plant on the grounds. This plant has been in use for a year and a half, includes over three thousand feet of pipe and is easily capable of extension to two thousand lights capacity whenever required.

Capt. A. W. Stiles, the Superintendent, writes under recent date that there has been no mishap whatever with it, that it is far cheaper than the system of gas lighting formerly in use at that institution, and he adds: "We consider it as safe as the safest of illuminating gases and the finest light known to date. It does not require skilled labor to operate the plant." A description of the plant with some detail may be found if desired in the issue of the Acetylene Gas Journal, for January, 1900.

Plants of sufficient size to serve for the illumination of towns or small villages, are not unknown and though they are not as yet numerous, still considerable progress has been made in pubic lighting by acetylene from central stations. There are three or four towns in Hungary, probably more in France and as many in Germany, half a dozen more in England and a few in the United States having regularly established acetylene gas companies which supply illumination to their customers in the same manner as that usual with coal gas companies. Though rather remote, it might be worth noticing, that a Greek engineer has established a plant in a town in Greece, purchasing his generators and fittings from Germany and importing carbide from Belgium; also that according to the Financial News, "shares in the Acetylene Gas Company of Rome have lately advanced very considerably in price." To come nearer home, the towns of Wabash and Dana, Indiana, have for some time been successfully lighted with acetylene, as has also the beautiful little borough

of Milford, Pike county, Pennsylvania. The writer paid a visit to Milford and found there not only the town plant operated by the Milford Gas Company, but also a number of independent acetylene plants at the hotels and some other properties. The company was chartered in July, 1898, and has several miles of service pipes in use, supplying gas to some fifty customers and furnishing the street illumination. The people generally spoke in the highest terms of the gas furnished and the light produced by it. One of the churches, a good sized structure, had received most satisfactory illumination at a total cost of twenty-four dollars per year.

There are other towns in which, like the above, acetylene is piped through the streets and sold by the meter, but as yet their number is small. A few years will doubtless witness a very perceptible growth in this direction.

BIBLIOGRAPHY.

A complete bibliography of acetylene would introduce a large number of foreign titles and very many references to the narrow scientific journals in all languages. Possibly a limited list of references, excluding all works in languages other than English and entering only to a very slight extent into the less popular periodicals, may be useful here and such an abbreviated or partial bibliography follows:

Acetylene Congress at Frankfort. Journ. Gas Ltg., Nov. 15, 1898.

Acetylene Explosion Panics. Editorial. Prog. Age, May 2, 1898.

Acetylene Explosions. Editorial. Am. Gas Lt. Journ., Feb. 14, 1898.

Acetylene Gas Accidents. Electr. Rev., Apr. 28, 1899.

Acetylene Gas, Cost of. Editorial. Prog. Age, Apr. 1, 1899.

Acetylene Gas Journal. Monthly since June, 1899. Acetylene Journal Publishing Co., Buffalo, N. Y.

Acetylene Installation at Wabash, Ind. Am. Gas Lt. Journ., Nov. 28, 1898.

Acetylene Manufacture, Some Theoretical Aspects of. Engineer, London, June 24, 1898.

Acetylene Plant for House Supplies. Journ. Gas Ltg., Oct. 4, 1898.

Acetylene Situation, The. Editorial. Prog. Age, Sept. 1, 1899.

Berlin Acetylene Exposition. Prog. Age, Apr. 15, 1898.

BOEHM, DR. L. K., Priority in Electrical Process for Making Calcium Carbide. Prog. Age, May 15, 1899.

BROWN, G. E., Recent Research on Acetylene. Prog. Age, July 15, 1897.

BULLIER, L. M., Application of Acetylene to Lighting. Prog. Age, Nov. 1. 1897.

BUTTERFIELD, W. J. A., Chemistry of Gas Manufacture. (Chapter XII, Acetylene.) London, 1898.

Calcium Carbide and Acetylene. Editorial. Am. Gas Ltg. Journ., Apr. 4, 1898.

Calcium Carbide and Acetylene. Industries and Iron. April 14, 1889.

Carbide Plant at Niagara Falls. Am. Gs. Lt. Journ., May 8, 1899.

Carbolite. Editorial. Prog. Age, Aug. 15, 1898.

CLOWES, PROF. F., Explosibility of Liquid Acetylene. Prog. Age, May 15, 1897.

COWLES, Calcium Carbide and Acetylene. Mineral Industry, Vol. VI, 1898, page 65.

CRAFTS, PROF. J. M., Lecture on Acetylene. Science, Mch. 13, 1896.

DAY, C. H., Calcium Carbide and Acetylene. U. S. Consular Reports, May 24, 1897.

Destruction of Liquefied Acetylene Works at Jersey City. Prog. Age, May 2, 1898.

DICKENSON, E. N., The Patent Side of Acetylene Gas. Prog. Age, July 15, 1897.

DUNCAN, R. K., Possibilities of Acetylene. Am. Gas Lt. Journ., Oct. 14, 1895.

DUNLAP, O. E., Illumination of College Buildings by Acetylene. Western Electrician, Aug. 21, 1897.

Explosive Acts. Order in Council Relating to Acetylene Gas. London, 1897.

FRASER, A. C., Priority in Discovery of Commercial Method of Making Calcium Carbide. Prog. Age, Feb. 1, 1898.

FRENCH, GEO., Acetylene. Wet Process. Heating and Vent., Oct. 15, 1898.

FULLER, H. F., Wet and Dry Generators. Heating and Vent., Oct. 15, 1898.

GERDES, H., Explosiveness of Acetylene Air Mixtures. Prog. Age, Dec. 1, 1898.

German Chemists Discuss Acetylene. Am. Gas Lt. Journ., May 24, 1897.

GIBBS, WM. E., Lighting by Acetylene. New York, 1898.

GLOVER, T., Acetylene Gas. The Gas World, Feb. 26, 1898.

GOODWIN, W. W., Acetylene. Paper before American Gas Light Association. Prog. Age, Nov. 15, 1895.

GOODWIN, W. W., Acetylene as an Enricher for Coal Gas. Prog. Age, June 1, 1898.

GOODWIN, W. W., Practical Uses of Acetylene. Paper before Western Gas Association. Prog. Age, June 15, 1896.

HEXAMER, Fire Underwriters' Rules for Safe Introduction of Acetylene. Journ. Franklin Institute, April, 1899.

HOLLIDAY, The Future of Acetylene. Gas World, April 17, 1897.

HOSPITALIER, E., Carbide of Calcium and Acetylene and their Applications. Prog. Age, May 1, 1896.

HOUSTON, KENNELLY AND KINNICUTT, Report on Present Status of Manufacture of Carbide of Calcium and Acetylene Gas. Prog. Age, Apr. 15, 1896.

JACOBUS, PROF. D. S., Artificial Light. Modern Methods Compared. Prog. Age, May 15, 1897.

JONES, LT. COL. W. A., The Wilmington Explosion. Am. Gas Lgt. Journ., Jan. 24, 1898.

JOUANNE, G., Dangers of Acetylene. Prog. Age, Feb. 15, 1898.

Journal of Acetylene Gas Lighting. Monthly since Jan., 1898. London, Eng.

KERSHAW, J. B. C., Progress in the Acetylene Gas Industry. Electrical Rev., London, Oct. 6, 1899.

KRAM, L. J., The Acetylene Gas Hazard. Scientific American, Oct. 8, 1898.

LEWES, PROF. V. B., Acetylene. A Lecture. Prog. Age, Dec. 15, 1897.

LEWES, PROF. V. B., Acetylene and its Modern Developments. Prog. Age, July 15, and Aug. 1, 1898.

LEWES, PROF. V. B., Conditions Existing in Generators. Prog. Age, Aug. 15, and Sept. 1, 1898.

LEWES, PROF. V. B., Acetylene. Cantor Lectures. Am. Gas Lgt. Journ., Dec. 12, 19, and 26, 1898, and Jan. 9, 1899.

London Acetylene Exhibition. Editorial. Prog. Age, Nov. 15, 1898.

LOWE, L. P., Artificial Illumination for Ordinary Business and Domestic Purposes. Am. Gas Lgt. Journ., Aug 7, 1899.

LUNGE AND CEDERCREUTZ, Analysis of Calcium Carbide and Acetylene, and Purification of the Latter. Gas World, Jan. 1, 1898.

McDAVITT, WM., Acetylene Gas Considered From the Firemen's Standpoint. The Sanitary Plumber. Oct. 2, 1899.

MASON, F. H., Calcium Carbide and Acetylene. U. S. Consular Report, May 24, 1897.

MASON, F. H., Present and Prospective Supply of Calcium Carbide. U. S. Consular Report, July 6, 1898.

MULLIKIN, A. H., The Use of Acetylene. Western Electrician, Oct. 9, 1897.

OLIVER, DR. T., Physiological Effects of Acetylene. Prog. Age, June 1, 1898.

PERRODIL, C. de., Carbide of Calcium and Acetylene. Translation of French Work. Prog. Age, commencing Apr. 1, 1898.

Petroleum Acts. Order in Council Relating to Calcium Carbide. London, 1897.

PHILLIPS, DR. F. C., Explosive Properties of Acetylene. Paper.

Journal of the Engineering Society of Western Pennsylvania, May, 1897.

Real Value of Acetylene as an Illuminant. The Engineer, Mch. 31, 1899.

RENOUF, PROF. E., The Use of Acetylene. Popular Sci. Monthly, Aug., 1899.

Report of the Acetylene Exhibition Committee. The Engineer. London, Mch. 3, 1899.

ROSEMANN, DR. R., Poisonous Properties of Acetylene. Prog. Age, Mch. 1, 1896.

SLOCUM, DR. F. L., Acetylene. Paper read before Western Gas Association. Prog. Age, June 1, 1895.

STUBBS, Generators and Essentials of Safety. Engineering. July 22, 1898.

THACKARA, Calcium Carbide and Acetylene in France. U. S. Consular Report, Aug. 4, 1898.

THOMPSON, G. F., Acetylene Gas and Calcium Carbide. London, 1898.

VENABLE, F. P., First Production of Calcium Carbide in the U. S. American Manufacturer, Dec. 16, 1898.

VENABLE AND CLARK, Some Properties of Calcium Carbide. Am. Gas Lgt. Journ., 1895, page 528.

WAHL, DR. W. H., Calcium Carbide and Acetylene. Journ. Frankl. Inst., Jan., 1895.

WILLSON, T. L., Calcium Carbide Process. U. S. Patent No. 541137, June 18, 1895.

WILLSON AND SUCKERT, Carbides and Acetylene Commercially Considered. Journ. Frankl. Inst., Apr., 1895.

WOLFF, P., Present Position of Acetylene Lighting. Journ. Gas Lgtg., Nov. 8 and 15, 1898.

WYATT, Calcium Carbide and Acetylene. Am. Gas Lgt. Journ., 1894, page 903.

NOTE.—The writer makes use of this opportunity to acknowledge his indebtedness to the Progressive Age, The J. B. Colt Company, The Mechanical Engineering Construction Company of New York, The Union Carbide Company of Chicago, and the Harris Manufacturing Company of Cleveland, as well as to various manufacturers of generators and burners who have kindly furnished cuts for the illustration of this article.